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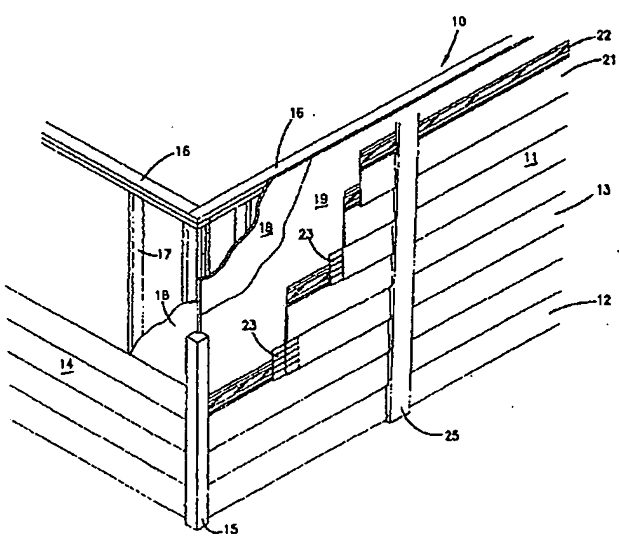
(54) Title: COMPOSITE SIDING SYSTEM AND METHODS OF MANUFACTURING AND INSTALLING SAME



(57) Abstract: A siding unit and method of manufacture and installation are disclosed. Each siding unit is a 2-part structure including a siding profile made of a thermoplastic-biofiber composite material and an upper flange made of a thermoplastic polymer. The upper flange is fastened to the siding profits.

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COMPOSITE SIDING SYSTEM AND METHODS OF MANUFACTURING AND INSTALLING SAME

This application is being filed as a PCT International Patent application on 12 January 2001, designating all countries, in the name of Andersen Corporation, a U.S. national corporation and resident, (Applicant for all countries except US); and Kurt Dalquist, Harold H. Evans, Giuseppe Puppin, Todd W. Bruchu and Kurt E. Heikkila, all U.S. citizens and residents (Applicants for US only).

Field of the Invention

The invention relates to an extruded or molded siding unit and siding systems made of a polymeric and fiber-polymeric composite material. The siding unit is adapted to be laid in overlapping courses to provide a weather-protective, ornamental exterior siding for houses and various other commercial and residential housings.

Background of the Invention

The exterior of houses and other structures are often protected by exterior siding products made of wood, vinyl, aluminum, bricks, stucco, and fiber reinforced composite materials such as wood fiber reinforced cement siding.

Brick has been a leading siding material for many years. Stucco has found significant use in new construction in the southern and western regions of the United States. Wood siding has also been a popular choice for many years. Traditional wood siding in a clapboard or shake is characterized by a tapered shape from a rather thick base portion to a rather thin upper edge. This design permits the siding to be nailed to the studs or other framing components of the house in overlapping relationship, in which the lower edge of each course overlaps the upper edge of the next lower course so as to shed rain.

Currently, aluminum, steel, hardboard, Masonite™, plywood and vinyl have dominated the siding market because of their lower cost as compared with brick, stucco or wood. Aluminum, steel, vinyl are favored due to low maintenance costs. These materials have been fabricated to simulate the shape and texture of the classic clapboards, wood shakes and shingles that consumers prefer.

The shapes and textures of the classic exterior surface materials produce attractive patterns of highlights and shadow lines on walls as the sun shifts in position during daylight.

Wood siding, while being attractive, requires periodic painting, staining or finishing. Wood siding may also be susceptible to insect attack if not finished properly. This type of siding may also experience uneven weathering for unfinished surfaces, and has a tendency to split, cup, check or warp. Wood shingle siding has the additional problem of being relatively slow to install. In addition, clear wood products are slowly becoming scarcer and are becoming more expensive.

In an effort to avoid these problems, aluminum siding was developed, and has enjoyed a widespread acceptance nationwide. Aluminum siding is normally made by a roll forming process and is factory painted or enameled so as to require substantially no maintenance during the life of the installation. However, metal siding tends to be energy inefficient and may transfer substantial quantities of heat.

More recently, rigid plastic material has been used as a substitute for aluminum siding, with the most typical siding material being made of a vinyl polymer, e.g. , polyvinyl chloride (PVC). Such plastic siding can be extruded in a continuous fashion or molded, after which lengths are cut to the desired length. Siding of this nature can be pigmented so as to be extruded or molded in the requisite color, thus avoiding the need for painting. However, it is difficult for the home-owner to refinish this type of siding in a different color.

While aluminum and plastic sidings have obvious advantages, such as a preformed surface finish and the elimination of maintenance, these siding choices pose certain inherent disadvantages. First, aluminum and plastic siding can be damaged when struck by a hard object such as stones, hail, or even a ladder which is carelessly handled. Repairing such dents in aluminum and plastic siding is difficult.

Conventional vinyl siding has an unattractive or unnatural softness or "give" to the touch," because extruded vinyl areas having less than about 0.100 of an inch in thickness are unduly flexible compared with the rigid look and feel of wood, stone, brick or stucco. As vinyl weathers, it becomes brittle. Thus, vinyl siding is more likely to crack or break as the siding ages.

In addition, most plastic and metal sidings are subject to "oil canning," i.e., surface distortions from temperature differences and unequal stress on different parts of the siding. These temperature differences cause unsightly bulges and depressions at the visible surface of the siding. Vinyl siding has a high coefficient of thermal expansion and contraction. In order to accommodate this and to achieve the desired protective coverage, an installer will often substantially overlap the vertical edges of vinyl siding. This causes noticeable, unattractive, outward bends in the ends of the overlapping end portions of the siding.

Moreover, conventional plastic siding often presents a poor imitation of wood textures and unattractive butt joints. Extruded vinyl siding often has a synthetic-appearing graining which is rolled into the extruded product after a partially congealed (solidified) "skin" has formed on the extruded product. Such a synthetic-appearing graining repeats itself at frequent intervals along the length of the vinyl siding. This frequent repetition is caused by a relatively short circumference around the hardened-steel roller die on which the makes the graining pattern. Consumers do not value such vinyl siding highly.

Fiber composite sidings including cellulosic fibers such as wood fiber and Kraft process paper fibers have been prepared by mixing the fibers with aqueous cement and clay slurries. The resulting fiber containing slurries are formed into planks and shakes by process technology similar to that used in the paper making industry. To form composite siding panels and planks, a liquid fiber-cement composite is rolled or pressed into the shape of the planks or panels, and then the green, de-watered, fiber-cement composite is cured. A typical siding cladding board and a cement containing formulation useful for making such siding boards are described in U.S. Patent Numbers 6,122,876 and 6,030,447 respectively.

Fiber-cement siding (FCS) products are installed by a siding contractor at a particular job site or a modular home manufacturer in a factory. To install FCS planks, for example, the planks are cut to a desired length and then nailed to plywood or wood-composite panels in a manner similar to hanging planks of cedar siding. After the FCS is installed, trim materials are generally attached to the structure. The FCS and the trim materials are then painted.

Fiber-cement composite siding (FCS) products offer several advantages compared to other types of siding materials. FCS is nonflammable, weatherproof, and relatively inexpensive to manufacture. Moreover, FCS does not rot and insects do not consume the fiber-cement composites. However FCS products must be maintained by painting. In addition, FCS is highly abrasive. It is often cut using abrasive disks, shear-like cutters and saws in a manner similar to cutting wood products with a hand-held power saw or a table saw. Cutting FCS frequently generates a very fine dust that creates an unpleasant working environment. Because fiber-cement composite materials are abrasive, cutters tend to wear out quickly.

Composite thermoplastic fiber materials have been used as a replacement for vinyl wood products. Such materials have enjoyed increasing utility in the prior art. A family of patents related to thermoplastic fiber composites are shown in U.S. Patent Nos. 5,441,801, 5,497,594, 5,539,027, 5,827,607, 5,932,334, 5,948,524, 6,004,668, 6,015,612 and 6,122,877 and others relating to thermoplastic composites using a biofiber such as a wood fiber in a high strength profile or structural member.

While the recent advances in thermoplastic composites using a wood fiber have improved the physical properties and appearance of fenestration products, special processing is required to manufacture these products. Producing a complex thermoplastic/wood composite profile is a complex and expensive process. If thermoplastic/wood composites are to be used as a replacement for vinyl wood products, the composite material must be capable of economic manufacture, ease of storage and transport and can be readily installed with simple hand tools in the field.

Accordingly, a substantial need exists for the development of a siding formed from a suitable composite material that can be directly formed by extrusion into reproducible, stable shapes advantageous for use as siding members. The siding structure must have resistance to weathering, relatively high strength and stiffness, an acceptable coefficient of thermal expansion, low thermal transmission, resistance to insect attack and rot, and a hardness and rigidity that permits sawing, milling, and fastener retention comparable to wood. The siding structure must be easily and economically formable and able to maintain reproducible stable dimensions, while

having the ability to be cut, milled, drilled and fastened at least as well as wooden members.

A substantial need exists for structurally strong, low life cycle cost, easily installed aesthetically pleasing siding systems.

Brief Discussion of the Invention

The invention includes a siding unit including a siding profile made of a thermoplastic-biofiber composite material and an upper flange fastened to the siding profile where the upper flange is made of a thermoplastic polymer.

The invention also includes a siding assembly for attachment to a building substrate, including a plurality of siding units, each siding unit having a siding profile made of a thermoplastic-biofiber composite material and an upper flange fastened to the siding profile where the upper flange is made of a thermoplastic polymer The siding assembly also includes a plurality of fasteners to fasten the siding units to a building substrate.

The invention also includes a siding unit formed by the process of fastening a thermoplastic-biofiber composite siding profile to a thermoplastic polymeric upper flange.

The invention further includes a method of manufacturing a siding unit including forming a siding profile, forming an upper flange and fastening the siding profile to the upper flange.

The invention further includes a method of installing siding including fastening a siding unit to a building substrate, each unit having a siding profile made of a thermoplastic-biofiber composite material and an upper flange fastened to the siding profile where the upper flange is made of a thermoplastic polymer.

The invention further includes building interface trim unit, including a elongated body having an inner face, an outer face, a first side edge and a second side edge parallel to the first side edge and having a serrated profile.

Brief Description of the Drawings

Figure 1A is a cross-sectional view of an embodiment of the upper flange.

Figure 1B is a cross-sectional view of an embodiment of the siding profile.

Figure 1C is a cross-sectional, end elevation view of a plurality of 2-part siding units, shown separately in Figure 1A and Figure 1B, installed on a building substrate.

Figure 1D is a front elevational view of the installed 2-part siding units shown in Figure 1C.

Figure 2A is a cross-sectional view of another embodiment of the upper flange.

Figure 2B is a cross-sectional view of another embodiment of the siding profile.

Figure 2C is a cross-sectional, end elevation view of a plurality of 2-part siding units, shown separately in Figure 2A and Figure 2B, installed on a building substrate.

Figure 2D is a front elevational view of the installed 2-part siding units shown in Figure 2C.

Figure 3A is a cross-sectional view of another embodiment of the upper flange.

Figure 3B is a cross-sectional view of another embodiment of the siding profile.

Figure 3C is a cross-sectional, end elevation view of a plurality of 2-part siding units, shown separately in Figure 3A and Figure 3B, installed on a building substrate.

Figure 3D is a front elevational view of the installed 2-part siding units shown in Figure 3C.

Figure 4A is a cross-sectional view of another embodiment of the upper flange.

Figure 4B is a cross-sectional view of another embodiment of the siding profile.

Figure 4C is a cross-sectional, end elevation view of a plurality of 2-part siding units, shown separately in Figure 4A and Figure 4B, installed on a building substrate.

Figure 4D is a front elevational view of the installed 2-part siding units shown in Figure 4C.

Figure 5A is a cross-sectional view of another embodiment of the upper flange.

Figure 5B is a cross-sectional view of another embodiment of the siding profile.

Figure 5C is a cross-sectional, end elevation view of a plurality of 2-part siding units, shown separately in Figure 5A and Figure 5B, installed on a building substrate.

Figure 5D is a front elevational view of the installed 2-part siding units shown in Figure 5C.

Figure 6A is a cross-sectional view of another embodiment of the upper flange.

Figure 6B is a cross-sectional view of another embodiment of the siding profile.

Figure 6C is a cross-sectional, end elevation view of a plurality of 2-part siding units, shown separately in Figure 6A and Figure 6B, installed on a building substrate.

Figure 6D is a front elevational view of the installed 2-part siding units shown in Figure 6C.

Figure 7A is a perspective view of an embodiment of a building interface trim piece.

Figure 7B is a side elevation view of the embodiment of a building interface trim piece shown in Figure 7A.

Figure 7C is the building interface trim piece view shown in Figure 7B assembled with a cross-sectional view of a cross-sectional, end elevation view of a plurality of 2-part siding units, shown in Figure 6C.

Figure 7D is an end elevation view of the embodiment of the building interface trim piece shown in Figure 7A.

Figure 7E is an end elevation view of an embodiment of an outside corner building interface trim piece shown in Figure 7A.

Figure 7F is an end elevation view of the embodiment of an inside corner building interface trim piece shown in Figure 7A.

Figure 7G is an end elevation view of the embodiment of another embodiment of a building interface trim piece shown in Figure 7A.

Figure 8A is a cross-sectional view of an embodiment of a spline.

Figure 8B is a front view of the embodiment of the spline shown in Figure 8A.

Figure 9A is a cross-sectional view of another embodiment of the spline.

Figure 9B is a front view of the embodiment of the spline shown in Figure 8B.

Figure 10 is a front view of two siding units butt-joined together with the spline shown in Figure 8A.

Figure 11 is a perspective view of a corner portion of a building having the siding of the present invention installed thereon, partially cutaway for viewing clarity.

Detailed Discussion of the Invention

The "siding profile" is defined as a profile that includes only one engagement channel for interlocking engagement with an adjacent siding unit. The siding profile is the lower part of a 2-part siding unit.

The "upper flange" is defined as a profile that includes only one engagement channel for interlocking engagement with an adjacent siding unit. The upper flange is the upper part of a 2-part siding unit.

The "engagement channel" is defined as a channel capable of interlocking with a second engagement channel. The engagement channel can be, for example, an "H" shaped channel, a "C" shaped channel, a "U" shaped channel or the like.

The "thermoplastic-biofiber composite material" is defined as material that is substantially composed of cellulosic fiber and thermoplastic polymer

wherein the thermoplastic forms a substantially continuous phase encapsulating a discontinuous fiber phase.

The "thermoplastic polymer" is defined as a synthetic high polymer that softens when heated above its glass transition temperature (T_g) but below its decomposition temperature (T_{Decomp}) and returns to its original condition with cooled to room temperature. "Thermoplastic Polymer" is also intended as thermoplastic polymer resins and/or mixtures thereof and/or thermoplastic copolymer resins which may or may not contain ingredients and/or additives including, but not limited to, stabilizers, lubricants, colorants, reinforcing particles, reinforcing fabric layers, laminates, surfacing layers, anti-foamants, anti-oxidants, fillers, foaming agents and/or other ingredients and/or additives for enhancing performance of the siding claimed herein.

The Coefficient of Thermal Expansion (COTE) of all materials is measured by the standard testing method ASTM D696.

All of the numerical values disclosed are modified by the term "about."

Figure 1A shows an embodiment of an upper flange 100. The upper flange 100 has an upper end 101 and a lower end 102. Near the lower end 102 is a receiver 125. The receiver 125 interlocks with an adjacent siding unit and is described further below. The receiver 125 has a "C" shape and is attached to the lower end 102 with a leg of the "C" shape. Between the point of attachment of the "C" shape and a terminus of the lower end 102, is an adjustment channel 135. The adjustment channel 135 allows an adjacent interlocking siding unit to be adjusted during installation. A lip 130 located at an unattached leg of the "C" shape. The lip 130 extends away from the lower end 102.

Between the adjustment channel 135 and the terminus of the lower end 102 is an overlap portion 110. The boundary between the adjustment channel 135 and overlap portion 110 is an offset 120. The offset 120 raises the overlap portion 110 above the adjustment channel 135 a distance that may be the thickness of a siding profile 150 as described below. Energy directors 115 may be on the overlap portion 110. The energy directors 115 project from a side of the overlap

portion 110. The energy directors 115 aid in thermal or ultrasonic fastening of the upper flange 100 to a siding profile 150 as described below.

A means for supporting 140 a second or adjacent siding profile 150 may be located at the upper end 101 of the upper flange 100. The means for supporting 140 provides physical support for a second or adjacent siding profile 150 to prevent the second or adjacent siding profile from failing. The means for supporting 140 can be an arch 145 structure. The arch 145 height is sufficient to provide physical support to a second or adjacent siding profile 150.

Figure 1B shows an embodiment of a siding profile 150. The siding profile 150 has an upper end 151 and a lower end 152. The siding profile 150 has a main body portion 165. The siding profile 150 has an inner surface 190 and an outer surface 195. The outer surface 195 of the main body portion 165 is exposed to the environment when installed. Near the lower end 152 is a nose 170. The nose 170 defines the boundary between the main body portion 165 and a bottom surface 175. The bottom surface 175 extends away from the nose 170 and creates a right or acute angle θ_1 between the inner surface 190 of the main body portion 165 and the inner surface 190 of the bottom surface 175. The bottom surface 175 extends to a rear leg 180. The rear leg 180 extends toward the upper end 151 and terminates at a lip 185. The lip 185 extends away from the inner surface 190. The main body portion 165, nose 170, bottom surface 175, rear leg 180 and lip 185 form a "U" shape and interlocks with the "C" shaped receiver 125 of an adjacent siding unit. The lip 185 and rear leg 180 interlocks the receiver 125 of an adjacent siding unit during installation as described below.

At the upper end 151 an offset 160 defines the boundary between a top edge 155 and the main body portion 165. The offset 160 lowers the top edge 155 below the main body portion 165 a distance that may be the thickness of the upper flange 100 as described below.

Figure 1C shows a side view of three 2-part siding units 103 installed on a building substrate 10 in overlapping horizontal courses. Each 2-part siding unit 103 includes the upper flange 100 shown in Figure 1A fastened to the siding profile 150 shown in Figure 1B. The upper flange 100 overlap portion 110 mates with

siding profile 150 top edge 155 and is secured or fastened together to form the 2-part siding unit 103.

The rear leg 180 and lip 185 of a first 2-part siding unit 103 engages the receiver 125 of a second 2-part siding unit 103 and interlocks the first 2-part siding unit 103 with the second 2-part siding unit 103. During installation, the directional alignment, both horizontal and vertical, of the second siding unit can be altered due to the adjustment channel 135 of the installed first siding unit. Alignment provides an even "reveal" of the siding profile. An even, "reveal" provides visually pleasing installed siding. Once aligned, the second siding unit can be fastened with a fastener 20 to the building substrate 10.

Drain holes 199 may be included on the lower end 152. Drain holes 199 allow water and debris to exit through the 2-part siding unit 103 to the environment. The drain holes 199 are located on at least a portion of the rear leg 180 or a portion of the bottom surface 175 so that the drain holes are not visible when the siding unit 103 is installed. The drain holes 199 may be any shape and have a surface area of at least 3/8 " square.

Figure 1C further shows the means for supporting 140 an adjacent 2-part siding unit 103. The means for supporting 140 is an arch 145 extending away from the building substrate 10 and the summit touching the inner surface 195 of the overlapping, adjacent siding profile 150. The arch 145 may define a cavity or be a solid structure 146. The solid structure can include porous material as described below.

Figure 1D shows a front view of the three 2-part siding units shown in Figure 1C. A protective layer or capstock layer 166 may be applied to the exposed portion or outer surface 195 of the main body portion 165. The upper flange 100 may have a plurality of elongated slots 111 arranged in a non-vertical order. The elongated slots 111 allow an installer flexibility to locate solid building substrate 10 to fasten the 2-part siding unit 103 with staples, nails, or the like (20). The elongated slots 111 also allow the 2-part siding unit 103 to move as the 2-part siding unit expands and contracts.

Figure 2A shows an embodiment of an upper flange 200. The upper flange 200 has an upper end 201 and a lower end 202. Near the lower end 202 is a

receiver 225. The receiver 225 interlocks with an adjacent siding unit and is described further below. The receiver 225 has a "C" shape and is attached to the lower end 202 with a leg of the "C" shape. Between the point of attachment of the "C" shape and a terminus of the lower end 202, is an adjustment channel 235. The adjustment channel 235 allows an adjacent interlocking siding unit to be adjusted during installation. A lip 230 located at an unattached leg of the "C" shape. The lip 230 extends away from the lower end 202.

Between the adjustment channel 235 and the terminus of the lower end 202 is an overlap portion 210. The boundary between the adjustment channel 235 and overlap portion 210 is an offset stop 220. The offset stop 220 is a ridge that raises above the adjustment channel 235 and overlap portion 210 a distance that may be the thickness of a siding profile 250 as described below. Energy directors (not shown) may be on the overlap portion 210 as was described above. The energy directors project from a side of the overlap portion 210. The energy directors aid in thermal or ultrasonic fastening of the upper flange 200 to a siding profile 250 as described below.

Figure 1B shows an embodiment of a siding profile 250. The siding profile 250 has an upper end 251 and a lower end 252. The siding profile 250 has a main body portion 265. The siding profile 250 has an inner surface 290 and an outer surface 295. The outer surface 295 of the main body portion 265 is exposed to the environment when installed. Near the lower end 252 is a nose 270. The nose 270 defines the boundary between the main body portion 265 and a bottom surface 275. The bottom surface 275 extends away from the nose 270 and creates a right or acute angle θ_2 between the inner surface 290 of the main body portion 265 and the inner surface 290 of the bottom surface 275. The bottom surface 275 extends to a rear leg 280. The rear leg 280 extends toward the upper end 251 and terminates at a lip 285. The lip 285 extends away from the inner surface 290. The main body portion 265, nose 270, bottom surface 275, rear leg 280 and lip 285 form a "U" shape and interlocks with the "C" shaped receiver 225 of an adjacent siding unit. The lip 285 and rear leg 280 interlocks the receiver 225 of an adjacent siding unit during installation as described below. At the upper end 251 is a top edge 255.

A means for supporting 240 the siding profile 250 may be located along the inner surface and extend away from the main body portion 265. The means for supporting 240 provides physical support to the siding profile 250 to prevent the siding profile 250 from failing. The means for supporting 240 can be a projection 245 structure. The projection 245 height is sufficient to provide physical support to the siding profile 250.

Figure 2C shows a side view of three 2-part siding units 203 installed on a building substrate 10 in overlapping horizontal courses. Each 2-part siding unit 203 includes the upper flange 200 shown in Figure 2A fastened to the siding profile 250 shown in Figure 2B. The upper flange 200 overlap portion 110 mates with siding profile 250 top edge 255 and is secured or fastened together to form the 2-part siding unit 203.

The rear leg 280 and lip 285 of a first 2-part siding unit 203 engages the receiver 225 of a second 2-part siding unit 203 and interlocks the first 2-part siding unit 203 with the second 2-part siding unit 203. During installation, the directional alignment of the second siding unit can be altered due to the adjustment channel 235 of the installed first siding unit. Once aligned, the second siding unit can be fastened with a fastener 20 to the building substrate 10.

Figure 2C further shows the means for supporting 240 the 2-part siding unit 103. The means for supporting 240 is a projection 245 extending away from the inner surface 295 of the siding profile 150 and the summit touching the building substrate 10. The projection 245 may define a cavity or be a solid structure. The solid structure can include porous material as described below.

Figure 2D shows a front view of the three 2-part siding units shown in Figure 2C. A protective layer or capstock layer 266 may be applied to the exposed portion or outer surface 295 of the main body portion 265. The upper flange 200 may have a plurality of elongated slots 211 arranged in a non-vertical order. The elongated slots 211 allow an installer flexibility to locate solid building substrate 10 to fasten the 2-part siding unit 203 with staples, nails, or the like (20). The elongated slots 211 also allow the 2-part siding unit 203 to move as the 2-part siding unit expands and contracts.

Figure 3A shows an embodiment of an upper flange 300. The upper flange 300 has an upper end 301 and a lower end 302. Near the lower end 302 is a receiver 325. The receiver 325 interlocks with an adjacent siding unit and is described further below. The receiver 325 has a "C" shape and is attached to the lower end 302 with a leg of the "C" shape. Between the point of attachment of the "C" shape and a terminus of the lower end 302, is an adjustment channel 335. The adjustment channel 335 allows an adjacent interlocking siding unit to be adjusted during installation. A lip 330 located at an unattached leg of the "C" shape. The lip 330 extends away from the lower end 302.

Between the adjustment channel 335 and the terminus of the lower end 302 is an overlap portion 310. The boundary between the adjustment channel 335 and overlap portion 310 is an offset 320. The offset 320 raises the overlap portion 310 above the adjustment channel 335 a distance that may be the thickness of a siding profile 350 as described below. Energy directors 315 may be on the overlap portion 310. The energy directors 315 project from a side of the overlap portion 310. The energy directors 315 aid in thermal or ultrasonic fastening of the upper flange 300 to a siding profile 350 as described below.

Figure 3B shows an embodiment of a siding profile 350. The siding profile 350 has an upper end 351 and a lower end 352. The siding profile 350 has a main body portion 365. The siding profile 350 has an inner surface 390 and an outer surface 395. The outer surface 395 of the main body portion 365 is exposed to the environment when installed. Near the lower end 352 is a nose 370. The nose 370 defines the boundary between the main body portion 365 and a bottom surface 375. The bottom surface 375 extends away from the nose 370 and creates a right or acute angle θ_2 between the inner surface 390 of the main body portion 365 and the inner surface 390 of the bottom surface 375. The bottom surface 375 extends to a rear leg 380. The rear leg 380 extends toward the upper end 351 and terminates at a lip 385. The lip 385 extends away from the inner surface 390. The main body portion 365, nose 370, bottom surface 375, rear leg 380 and lip 385 form a "U" shape and interlocks with the "C" shaped receiver 325 of an adjacent siding unit. The lip 385 and rear leg 380 interlocks the receiver 325 of an adjacent siding unit during installation as described below.

At the upper end 351 an offset 360 defines the boundary between a top edge 355 and the main body portion 365. The offset 360 lowers the top edge 355 below the main body portion 365 a distance that may be the thickness of the upper flange 300 as described below. A second offset 361 may also be provided also.

A means for supporting 340 the siding profile 350 may be located along the inner surface and extend away from the main body portion 365. The means for supporting 340 provides physical support to the siding profile 350 to prevent the siding profile 350 from failing. The means for supporting 340 can be a projection 345 structure. The projection 345 height is sufficient to provide physical support to the siding profile 350.

Figure 3C shows a side view of three 2-part siding units 303 installed on a building substrate 10 in overlapping horizontal courses. Each 2-part siding unit 303 includes the upper flange 300 shown in Figure 3A fastened to the siding profile 350 shown in Figure 3B. The upper flange 300 overlap portion 310 mates with siding profile 350 top edge 355 and is secured or fastened together to form the 2-part siding unit 303.

The rear leg 380 and lip 385 of a first 2-part siding unit 303 engages the receiver 325 of a second 2-part siding unit 303 and interlocks the first 2-part siding unit 303 with the second 2-part siding unit 303. During installation, the directional alignment of the second siding unit can be altered due to the adjustment channel 335 of the installed first siding unit. Once aligned, the second siding unit can be fastened with a fastener 20 to the building substrate 10.

Figure 3C further shows the means for supporting 340 the 2-part siding unit 303. The means for supporting 340 is a projection 345 extending away from the inner surface 395 of the siding profile 350 and the summit touching the building substrate 10. The projection 345 may define a cavity or be a solid structure. The solid structure can include porous material as described below.

Figure 3D shows a front view of the three 2-part siding units shown in Figure 3C. A protective layer or capstock layer 366 may be applied to the exposed portion or outer surface 395 of the main body portion 365. The upper flange 300 may have a plurality of elongated slots 311 arranged in a non-vertical

order. The elongated slots 311 allow an installer flexibility to locate solid building substrate 10 to fasten the 2-part siding unit 303 with staples, nails, or the like (20). The elongated slots 311 also allow the 2-part siding unit 303 to move as the 2-part siding unit expands and contracts.

Figure 4A shows an embodiment of an upper flange 400. The upper flange 400 has an upper end 401 and a lower end 402. Near the lower end 402 is a receiver 425. The receiver 425 interlocks with an adjacent siding unit and is described further below. The receiver 425 has a "C" shape and is attached to the lower end 402 with a leg of the "C" shape. Between the point of attachment of the "C" shape and a terminus of the lower end 402, is an adjustment channel 435. The adjustment channel 435 allows an adjacent interlocking siding unit to be adjusted during installation. A lip 430 located at an unattached leg of the "C" shape. The lip 430 extends away from the lower end 402.

Between the adjustment channel 435 and the terminus of the lower end 402 is an overlap portion 410. The boundary between the adjustment channel 435 and overlap portion 410 is an offset 420. The offset 420 raises the overlap portion 410 above the adjustment channel 435 a distance that may be the thickness of a siding profile 450 as described below. Energy directors 415 may be on the overlap portion 410. The energy directors 415 project from a side of the overlap portion 410. The energy directors 415 aid in thermal or ultrasonic fastening of the upper flange 400 to a siding profile 450 as described below.

Figure 4B shows an embodiment of a siding profile 450. The siding profile 450 has an upper end 451 and a lower end 452. The siding profile 450 has a main body portion 465. The siding profile 450 has an inner surface 490 and an outer surface 495. The outer surface 495 of the main body portion 465 is exposed to the environment when installed. Near the lower end 452 is a nose 470. The nose 470 defines the boundary between the main body portion 465 and a bottom surface 475. The bottom surface 475 extends away from the nose 470 and creates a right or acute angle θ_4 between the inner surface 490 of the main body portion 465 and the inner surface 490 of the bottom surface 475. The bottom surface 475 extends to a rear leg 480. The rear leg 480 extends toward the upper end 451 and terminates at a lip 485. The lip 485 extends away from the inner surface 490. The main body portion 465,

nose 470, bottom surface 475, rear leg 480 and lip 485 form a "U" shape and interlocks with the "C" shaped receiver 425 of an adjacent siding unit. The lip 485 and rear leg 480 interlocks the receiver 425 of an adjacent siding unit during installation as described below.

At the upper end 451 an offset 460 defines the boundary between a top edge 455 and the main body portion 465. The offset 460 lowers the top edge 455 below the main body portion 465 a distance that may be the thickness of the upper flange 400 as described below.

Figure 4C shows a side view of three 2-part siding units 403 installed on a building substrate 10 in overlapping horizontal courses. Each 2-part siding unit 403 includes the upper flange 400 shown in Figure 4A fastened to the siding profile 450 shown in Figure 4B. The upper flange 400 overlap portion 410 mates with siding profile 450 top edge 455 and is secured or fastened together to form the 2-part siding unit 403.

The rear leg 480 and lip 485 of a first 2-part siding unit 403 engages the receiver 425 of a second 2-part siding unit 403 and interlocks the first 2-part siding unit 403 with the second 2-part siding unit 403. During installation, the directional alignment of the second siding unit can be altered due to the adjustment channel 435 of the installed first siding unit. Once aligned, the second siding unit can be fastened with a fastener 20 to the building substrate 10.

Figure 4D shows a front view of the three 2-part siding units shown in Figure 4C. A protective layer or capstock layer 466 may be applied to the exposed portion or outer surface 495 of the main body portion 465. The upper flange 400 may have a plurality of elongated slots 411 arranged in a non-vertical order. The elongated slots 411 allow an installer flexibility to locate solid building substrate 10 to fasten the 2-part siding unit 403 with staples, nails, or the like (20). The elongated slots 411 also allow the 2-part siding unit 403 to move as the 2-part siding unit expands and contracts.

Figure 5A shows an embodiment of an upper flange 500. The upper flange 500 has an upper end 501 and a lower end 502. Near the lower end 502 is a receiver 525. The receiver 525 interlocks with an adjacent siding unit and is described further below. The receiver 525 has a "C" shape and is attached to the

lower end 502 with a leg of the "C" shape. Between the point of attachment of the "C" shape and a terminus of the lower end 502, is an adjustment channel 535. The adjustment channel 535 allows an adjacent interlocking siding unit to be adjusted during installation. A lip 530 located at an unattached leg of the "C" shape. The lip 530 extends away from the lower end 502.

Between the adjustment channel 535 and the terminus of the lower end 502 is an overlap portion 510. The boundary between the adjustment channel 535 and overlap portion 510 is an offset 520. The offset 520 raises the overlap portion 510 above the adjustment channel 535 a distance that may be the thickness of a siding profile 550 as described below. Energy directors 515 may be on the overlap portion 510. The energy directors 515 project from a side of the overlap portion 510. The energy directors 515 aid in thermal or ultrasonic fastening of the upper flange 500 to a siding profile 550 as described below.

A means for supporting 540 a second or adjacent siding profile 550 may be located at the upper end 501 of the upper flange 500. The means for supporting 540 provides physical support for a second or adjacent siding profile 550 to prevent the second or adjacent siding profile from failing. The means for supporting 540 can be a fin 545 structure. The fin 545 height is sufficient to provide physical support to a second or adjacent siding profile 550.

Figure 5B shows an embodiment of a siding profile 550. The siding profile 550 has an upper end 551 and a lower end 552. The siding profile 550 has a main body portion 565. The siding profile 550 has an inner surface 590 and an outer surface 595. The outer surface 595 of the main body portion 565 is exposed to the environment when installed. Near the lower end 552 is a nose 570. The nose 570 defines the boundary between the main body portion 565 and a bottom surface 575. The bottom surface 575 extends away from the nose 570 and creates an right or acute angle θ_5 between the inner surface 590 of the main body portion 565 and the inner surface 590 of the bottom surface 575. The bottom surface 575 extends to a rear leg 580. The rear leg 580 extends toward the upper end 551 and terminates at a lip 585. The lip 585 extends away from the inner surface 590. The main body portion 565, nose 570, bottom surface 575, rear leg 580 and lip 585 form a "U" shape and interlocks with the "C" shaped receiver 525 of an adjacent siding unit.

The lip 585 and rear leg 580 interlocks the receiver 525 of an adjacent siding unit during installation as described below.

At the upper end 551 an offset 560 defines the boundary between a top edge 555 and the main body portion 565. The offset 560 lowers the top edge 555 below the main body portion 565 a distance that may be the thickness of the upper flange 500 as described below.

Figure 5C shows a side view of three 2-part siding units 503 installed on a building substrate 10 in overlapping horizontal courses. Each 2-part siding unit 503 includes the upper flange 500 shown in Figure 5A fastened to the siding profile 550 shown in Figure 5B. The upper flange 500 overlap portion 510 mates with siding profile 550 top edge 555 and is secured or fastened together to form the 2-part siding unit 503.

The rear leg 580 and lip 585 of a first 2-part siding unit 503 engages the receiver 525 of a second 2-part siding unit 503 and interlocks the first 2-part siding unit 503 with the second 2-part siding unit 503. During installation, the directional alignment of the second siding unit can be altered due to the adjustment channel 535 of the installed first siding unit. Once aligned, the second siding unit can be fastened with a fastener 20 to the building substrate 10.

Figure 5C further shows the means for supporting 540 an adjacent 2-part siding unit 503. The means for supporting 540 is a fin 545 extending away from the building substrate 10 and the summit touching the inner surface 595 of the overlapping, adjacent siding profile 550. The fin 545 may define a cavity or be a solid structure 546. The solid structure can include porous material as described below.

Figure 5D shows a front view of the three 2-part siding units shown in Figure 5C. A protective layer or capstock layer 566 may be applied to the exposed portion or outer surface 595 of the main body portion 565. The upper flange 500 may have a plurality of elongated slots 511 arranged in a non-vertical order. The elongated slots 511 allow an installer flexibility to locate solid building substrate 10 to fasten the 2-part siding unit 503 with staples, nails, or the like (20). The elongated slots 511 also allow the 2-part siding unit 503 to move as the 2-part siding unit expands and contracts.

Figure 6A shows an embodiment of an upper flange 600. The upper flange 600 has an upper end 601 and a lower end 602. Near the lower end 602 is a receiver 625. The receiver 625 interlocks with an adjacent siding unit and is described further below. The receiver 625 has a "C" shape and is attached to the lower end 602 with a leg of the "C" shape. Between the point of attachment of the "C" shape and a terminus of the lower end 602, is an adjustment channel 635. The adjustment channel 635 allows an adjacent interlocking siding unit to be adjusted during installation. A lip 630 located at an unattached leg of the "C" shape. The lip 630 extends away from the lower end 602.

Between the adjustment channel 635 and the terminus of the lower end 602 is an overlap portion 610. The boundary between the adjustment channel 635 and overlap portion 610 is an offset 620. The offset 620 raises the overlap portion 610 above the adjustment channel 635 a distance that may be the thickness of a siding profile 650 as described below. Energy directors 615 may be on the overlap portion 610. The energy directors 615 project from a side of the overlap portion 610. The energy directors 615 aid in thermal or ultrasonic fastening of the upper flange 600 to a siding profile 650 as described below.

Figure 6B shows an embodiment of a siding profile 650. The siding profile 650 has an upper end 651 and a lower end 652. The siding profile 650 has a main body portion 665. The siding profile 650 has an inner surface 690 and an outer surface 695 that define a cavity 653. The outer surface 695 of the main body portion 665 is exposed to the environment when installed. Near the lower end 652 is a nose 670. The nose 670 defines the boundary between the main body portion 665 and a bottom surface 675. The bottom surface 675 extends away from the nose 670 and creates a right or acute angle θ_6 between the inner surface 690 of the main body portion 665 and the inner surface 690 of the bottom surface 675. The bottom surface 675 extends to a rear leg 680. The rear leg 680 extends toward the upper end 651 and terminates at a lip 685. The lip 685 extends away from the inner surface 690. The main body portion 665, nose 670, bottom surface 675, rear leg 680 and lip 685 form a "U" shape and interlocks with the "C" shaped receiver 625 of an adjacent siding unit. The lip 685 and rear leg 680 interlocks the receiver 625 of an adjacent siding unit during installation as described below.

At the upper end 651 an offset 660 defines the boundary between a top edge 655 and the main body portion 665. The offset 660 lowers the top edge 655 below the main body portion 665 a distance that may be the thickness of the upper flange 600 as described below.

Figure 6C shows a side view of three 2-part siding units 603 installed on a building substrate 10 in overlapping horizontal courses. Each 2-part siding unit 603 includes the upper flange 600 shown in Figure 6A fastened to the siding profile 650 shown in Figure 6B. The upper flange 600 overlap portion 610 mates with siding profile 650 top edge 655 and is secured or fastened together to form the 2-part siding unit 603.

The rear leg 680 and lip 685 of a first 2-part siding unit 603 engages the receiver 625 of a second 2-part siding unit 603 and interlocks the first 2-part siding unit 603 with the second 2-part siding unit 603. During installation, the directional alignment of the second siding unit can be altered due to the adjustment channel 635 of the installed first siding unit. Once aligned, the second siding unit can be fastened with a fastener 20 to the building substrate 10.

Figure 6C further shows the means for supporting 640 a 2-part siding unit 603. The means for supporting 640 is a bridge 654a extending between the main body portion 265 and the inner surface 690 or material 654b at least partially filling the cavity 653. The bridge 654a or material 654b can be formed from solid, porous or foamed material as described below.

Figure 6D shows a front view of the three 2-part siding units shown in Figure 6C. A protective layer or capstock layer 666 may be applied to the exposed portion or outer surface 695 of the main body portion 665. The upper flange 600 may have a plurality of elongated slots 611 arranged in a non-vertical order. The elongated slots 611 allow an installer flexibility to locate solid building substrate 10 to fasten the 2-part siding unit 103 with staples, nails, or the like (20). The elongated slots 611 also allow the 2-part siding unit 603 to move as the 2-part siding unit expands and contracts.

Figure 7A shows an embodiment of a building interface trim unit 700. The building interface trim unit 700 includes an outer surface 705 and an inner surface 710. A first side edge 715 runs along the inner surface. A second side edge

720 runs parallel to the first side edge 715. The second side edge 720 had a serrated profile 725 to mate with the 2-part siding unit's siding profile 150, 250, 350, 450, 550, 650 when installed on a building 10. The building interface trim unit 700 can be planar as shown or be oriented to provide an inside or outside corner. The building interface trim unit 700 can be formed by molding or extrusion.

The building interface trim unit 700 provides a barrier to a substantial portion of environmental water. The building interface trim unit 700 allows for some environmental water to pass by the serrated profile 725. Water that enters the building interface trim unit 700 is directed out of the building interface trim unit 700 via drainage channels 730. The building interface trim unit 700 can be made of conventional fenestration materials or materials disclosed herein to make the components of the 2-part siding units.

Figure 7B is a side elevation view of the embodiment of a building interface trim piece shown in Figure 7A. The building interface trim unit 700 includes an outer surface 705 and an inner surface 710. A first side edge 715 runs along the inner surface. A second side edge 720 runs parallel to the first side edge 715. The second side edge 720 had a serrated profile 725 to mate with the 2-part siding unit's siding profile 150, 250, 350, 450, 550, 650 when installed on a building 10.

Figure 7C is the building interface trim piece view shown in Figure 7B assembled with a cross-sectional view of a cross-sectional, end elevation view of a plurality of 2-part siding units, shown in Figure 6C. The building interface trim unit 700 is adapted to mate with any overlapping siding assemblies.

Figure 7D is an end elevation view of the embodiment of the building interface trim piece shown in Figure 7A. The building interface trim unit 700 includes an outer surface 705 and an inner surface 710. A first side edge 715 runs along the inner surface. A second side edge 720 runs parallel to the first side edge 715. The second side edge 720 had a serrated profile 725 to mate with the 2-part siding unit's siding profile 150, 250, 350, 450, 550, 650 when installed on a building 10.

Figure 7E is an end elevation view of an embodiment of an outside corner building interface trim piece shown in Figure 7A. The building interface trim

unit 700 includes an outer surface 705 and an inner surface 710. A first side edge 715 runs along the inner surface. A second side edge 720 runs parallel to the first side edge 715. The second side edge 720 had a serrated profile 725 to mate with the 2-part siding unit's siding profile 150, 250, 350, 450, 550, 650 when installed on a building 10.

Figure 7F is an end elevation view of the embodiment of an inside corner building interface trim piece shown in Figure 7A. The building interface trim unit 700 includes an outer surface 705 and an inner surface 710. A first side edge 715 runs along the inner surface. A second side edge 720 runs parallel to the first side edge 715. The second side edge 720 had a serrated profile 725 to mate with the 2-part siding unit's siding profile 150, 250, 350, 450, 550, 650 when installed on a building 10.

Figure 7G is an end elevation view of the embodiment of another embodiment of a building interface trim piece shown in Figure 7A. The building interface trim unit 700 includes an outer surface 705 and an inner surface 710. A first side edge 715 runs along the inner surface. A second side edge 720 runs parallel to the first side edge 715. The second side edge 720 had a serrated profile 725 to mate with the 2-part siding unit's siding profile 150, 250, 350, 450, 550, 650 when installed on a building 10.

Figure 8A is side view of an embodiment of a spline 800. The spline 800 is a means for joining adjacent siding units. The spline 800 spans two adjacent 2-part siding units to form a butt-joint. The spline 800 is sized and configured to fit against an inner surface of the siding profile. The spline 800 may include energy directors 815 located along the length of the spline 800 on the spline member 805. The energy directors 815 aid in thermal or ultrasonic fastening of the spline 800 to a siding profile. The spline 800 includes a lower portion 810 that is sized and configured to fit within a lower engagement channel of a siding profile. The spline 800 can add structural strength to the butt-joint. The spline can be made of thermoplastic or thermoplastic-biofiber material.

Figure 8B is a front view of the embodiment shown in Figure 8A. The spline 800 includes a spline member 805 and a lower portion 810 as described above.

Figure 9A is a side view of another embodiment of a spline 900. The spline 900 is a means for joining adjacent siding units. The spline 900 spans two adjacent 2-part siding units to form a butt-joint. The spline 900 is sized and configured to fit against an inner surface of the siding profile. The spline 900 may include energy directors 915 located along the length of the spline 900 on the spline member 905. The energy directors 915 aid in thermal or ultrasonic fastening of the spline 900 to a siding profile. The spline 900 includes a lower portion 910 that is sized and configured to fit within a lower engagement channel of a siding profile. The spline 900 can add structural strength to the butt-joint. The spline can be made of thermoplastic or thermoplastic-biofiber material. The lower portion 910 may be mode out of thermoplastic, thermoplastic-biofiber, metal or other material that provides a sufficient tensile strength to provide structural support to the butt-joint, such as, for example, metal rods.

Figure 9B is a front view of the embodiment shown in Figure 9A. The spline 900 includes a spline member 905 and a lower portion 910 as described above.

Figure 10 is a front view of two 2-part siding units butt-joined together 1000. Each 2-part siding unit 1001 includes a upper flange 1005 and a siding profile 1010. A spline 1020 is secured to a portion of each siding profile 1010. The spline is secured to an inner surface of the siding profile 1010 so that it is not visible when installed. The upper flange may have a plurality of elongated slots 1011 arranged in a non-vertical order. The elongated slots 1011 can be arranged in any order as illustrated in Figure 10.

Figure 11 depicts framing construction in a house or similar building substrate 10 in which the inventive siding system is installed on the exterior surface. Although the invention is applicable to buildings and structures of all types, it will be described for convenience and ease of description relative to a house.

The house 10 is covered by a plurality of elongated, horizontal 2-part siding units 11. The 2-part siding units 11 may be installed on all of the exterior wall surfaces 12 of the house. The house 10 has a side wall 13 and an end wall 14. A outside corner of the building between the walls 13, 14 has a concave vertical

building interface trim unit 15. The house may also have a planar vertical building interface trim unit 25 along the side wall 13.

Ceiling or header joists 16 and wall studs 17 make up a portion of the house's frame structure. The header 16 and studs 17 may be made of wood (as shown) or may be made from aluminum channels or steel channels, or other structural, load-supporting members. The wall structure includes a sheathing layer 18, such as a layer of plywood, particleboard, or other suitable sheathing or structural layer. This sheathing layer 18 is secured to the studs 17 and header 16. Over the sheathing layer 18 is a water or air barrier sheet layer 19, for example, comprised of asphalt-impregnated building felt paper, or a non-woven housewrap material, such as TYVEK™ available from E.I. DuPont Inc., or the like. The lower part of each 2-part siding unit's siding profile portion 21 overlaps and covers the upper flange 22 of the next lower 2-part siding unit 11, and the 2-part siding units are in hook engagement as will be described below.

Two 2-part siding units 11 can be butt-joined with a spline 23. The spline 23 can be installed before the 2-part siding unit 11 is installed. The spline 23 may be secured to the 2-part siding units 11 forming a solid butt-joint.

When the siding system is installed on the building 10, a starter trim strip (not shown) is first fastened on the bottom periphery of each side of the house 10. The strip may be a conventional "J-channel" formed with its own nailing flange shown in detail below. After the starter strip is secured in place, a first course 12 of 2-part siding is installed horizontally along the width of a wall surface of the house 10. The lower edge of each elongated 2-part siding unit 12 is dropped into the U-channel in the starter strip, and the 2-part siding unit 12 is secured in place against the house 10 by a plurality of fasteners 20 driven through the slots in the upper flange. Then, a second and successive courses of 2-part siding units 11 are similarly installed in place. A vertical building interface trim piece 15 covers the corner joint.

When the course of 2-part siding units 11 reach the top of a wall surface, a building interface trim unit or accessory strip (not shown) is provided, which either caps off the siding system on that side of the house or provides a connection between the vertical wall surface and the other surfaces of the side, such as the soffit, overhang or fascia (not shown). Building interface trim units can be

used to finish off the building surfaces on the edges, corners and around windows and doors.

2-Part Siding Structure

The siding structure of the invention is a 2-part siding unit that includes a siding profile and an upper flange. The upper flange and siding profile can be separately formed and subsequently joined together to form the 2-part siding unit. Since the siding profile and upper flange each have a single engagement channel, a final siding unit includes both a siding profile and upper flange joined together. This 2-part siding unit is capable of interlocking with a second adjacent siding unit. The upper flange engagement channel may engage and interlock with the siding profile engagement channel of an adjacent two-part siding unit as the 2-part siding units are installed on a building substrate. The upper flange may be fastened to the siding profile in a continuous or intermittent fashion.

The upper flange and siding profile can have different physical properties. The upper flange may have a coefficient of thermal expansion (COTE) greater than the COTE for the siding profile. The upper flange's COTE may be 1.5 times, 2 times or greater than the siding profile's COTE. Bonding two materials together with different COTEs causes material deformation or deflection at the boundary of the two materials as the temperature changes. Bimetal thermometers commonly illustrate this concept. Surprisingly, a siding unit formed by joining two materials with such different COTEs provides many advantages and negligible COTE deformation problems.

The 2-part siding unit may include means for supporting the siding profile or an adjacent siding profile as described above. The means for supporting functions to absorb static and dynamic impact forces directed at the siding unit. The means for supporting can be located between the siding profile and building substrate when installed on a building substrate. The means for supporting can be made of any material or combination of materials for example, thermoplastic polymer, thermoplastic-biofiber composite material, or foams. The means for supporting can be any shape or structure for example, an arch, a fin, or a projection. The means for supporting prevents the 2-part siding unit from fracturing (failing) on either a micro or macroscopic level, when impacted by environmental or incidental

contacts such as, for example, projectile, hail, ladders, and utility or construction work.

Upper Flange

The upper flange can be a thermoplastic polymer. The thermoplastics can include polyolefins such as polyethylene, polypropylene or other thermoplastic polymers such as polyvinyl chloride, polystyrene, polyacrylic materials, polyester materials and other common thermoplastics. Thermoplastic polymers can be extruded into complex profiles economically.

The upper flange may not be exposed to the environment, thus the material selected to form the upper flange can be a lower grade thermoplastic or less costly material since it may not be exposed to sunlight or weathering. The upper flange may not require a protective capstock coating since the upper flange may not be exposed to the environment. Thus, the material used to form the upper flange can be selected based on the material strength, flexibility, ease of extrusion and low material cost.

The thickness of the upper flange can range from 0.6 to 1.9 mm (0.025 to 0.075 inch) and all numerical values subsumed therein or 1.3 mm (0.05 inch). The upper flange COTE can range from 4.5×10^{-5} m/m/°C (2.5×10^{-5} in/in/°F) to 6×10^{-5} m/m/°C (3.4×10^{-5} in/in/°F) and all numerical values subsumed therein.

The upper flange may include energy directors on the overlap portion. The energy directors can be formed of the same material as the upper flange. Energy directors are projections that focus the energy used to secure the upper flange to the siding profile and aid in fastening the upper flange to the siding profile. One or more energy directors may be provided. The energy director may be continuous or intermittent along the length of the upper flange. The energy directors can be any shape and may be 0.4 mm (0.015 inch) high and 0.5 mm (0.02 inch) wide.

The upper flange may have a plurality of elongated slots arranged in a non-vertical order. The elongated slots allow an installer flexibility to locate solid building substrate to fasten the 2-part siding unit with staples, nails, or the like. The elongated slots also allow the 2-part siding unit to move as the 2-part siding unit expands and contracts.

Siding profile

The siding profile can be a composite of a thermoplastic polymer and a biofiber; however, the siding profile may be a thermoplastic polymer material alone. The thermoplastics can include polyolefins such as polyethylene, polypropylene or other thermoplastic polymers such as polyvinyl chloride, polystyrene, polyacrylic materials, polyester materials and other common thermoplastics. The biofiber may include any cellulosic fibers such as wood fibers. In contrast to vinyl siding, as the biofiber-thermoplastic composite weathers, the ductility of the material improves.

The siding profile can be a solid "open" profile or a hollow profile. The hollow profile can be at least partially filled with a foam or have "bridges" that form a web structure within the hollow profile. The bridges can be solid or a foam material. The thickness of the solid siding profile can range from 2.5 to 3.8 mm (0.1 to 0.15 inch) and all numerical values subsumed therein or 3.2 mm (0.12 inch). The siding profile COTE can range from 4.5×10^{-5} m/m/°C (2.5×10^{-5} in/in/°F) to 3×10^{-5} m/m/°C (1×10^{-5} in/in/°F) and all numerical values subsumed therein. The siding profile can be a single (see Figure 1), double (see Figure 5) or more, faced profile.

A thermoplastic-biofiber composite combines 10 to 50, and all numerical values subsumed therein, parts of a polyolefin such as a polyethylene or polypropylene homopolymer or copolymer with greater than 50 to 90, and all numerical values subsumed therein, parts of a fiber having an aspect ratio greater than 2. Useful polyolefin material is a polyethylene or polypropylene polymer having a melting point of 140 to 160°C or 145 to 158°C. The polyethylene material can be, for example, a polyethylene homopolymer or copolymer with 0.01 to 10wt% of a $C_{2\text{-}16}$ olefin monomer. The polypropylene material can be, for example, a polypropylene homopolymer or copolymer with 0.01 to 10 wt% of ethylene or a $C_{4\text{-}16}$ olefin monomer or mixtures thereof. This polymer can have a melt flow index of less than 1.0 g-10 min^{-1} or 0.5 g-10 min^{-1} when extruded or from 2 to 20 g-10 min^{-1} when the composite is injection molded. The melt flow index is determined in accord with ASTM 1238.

The composite can also compatibilized using a compatibilizing agent that promotes the desired intimate contact between polymer and fiber whereby fiber

particles are encapsulated by a continuous polymer phase. The biofiber can be dried to a content of less than 5000 parts, or less than 3500 parts of water per each million parts (ppm) of fiber to promote the encapsulated morphology which applicants believe results from opening fiber cellular structure to wetting and penetration by fluidized thermoplastic polymer. The combination of these factors results in a composite having surprisingly improved structural and thermal properties. A representative polypropylene random copolymer is Montell SV-258. Representative compatibilizers are Eastman Epolene™ Series – E43, G3003, G0315, etc.

The composite can also include a polyvinyl chloride and biofiber composite. Polyvinyl chloride (PVC) is a common commodity thermoplastic polymer that can be used in the composite. PVC homopolymers in a variety of molecular weights (K values) are readily available from a number of sources, GEON and Shin-Tech, for example. Polyvinyl chloride can also be combined with other vinyl monomers in the manufacture of polyvinyl chloride copolymers. Such copolymers can be linear copolymers, branched copolymers, graft copolymers, random copolymers, regular repeating copolymers, block copolymers, etc. Monomers that can be combined with vinyl chloride to form vinyl chloride copolymers include a acrylonitrile; alpha-olefins such as ethylene, propylene, etc.; chlorinated monomers such as vinylidene dichloride, acrylate monomers such as acrylic acid, methylacrylate, methylmethacrylate, acrylamide, hydroxyethyl acrylate, and others; styrenic monomers such as styrene, alphamethyl styrene, vinyl toluene, etc.; vinyl acetate; and other commonly available ethylenically unsaturated monomer compositions.

Such monomers can be used in an amount up to 50 mol-%, the balance being vinyl chloride. Polymer blends or polymer alloys can be useful in manufacturing the pellet or linear extrudate of the invention. Such alloys comprise two miscible polymers blended to form a uniform composition. Scientific and commercial progress in the area of polymer blends has lead to the realization that important physical property improvements can be made not by developing new polymer material but by forming miscible polymer blends or alloys. A polymer alloy at equilibrium comprises a mixture of two amorphous polymers existing as a single phase of intimately mixed segments of the two macro molecular components.

Miscible amorphous polymers form glasses upon sufficient cooling and a homogeneous or miscible polymer blend exhibits a single, composition dependent glass transition temperature (T_g). Immiscible or non-alloyed blend of polymers display two or more glass transition temperatures associated with immiscible polymer phases. In the simplest cases, the properties of polymer alloys reflect a composition weighted average of properties possessed by the components. In general, however, the property dependence on composition varies in a complex way with a particular property, the nature of the components (glassy, rubbery or semicrystalline), the thermodynamic state of the blend, and its mechanical state whether molecules and phases are oriented. Polyvinyl chloride forms a number of polymer alloys including, for example, polyvinyl chloride/nitrile rubber; polyvinyl chloride and related chlorinated copolymers and terpolymers of polyvinyl chloride or vinylidene dichloride polyvinyl chloride/alphamethyl styrene-acrylonitrile copolymer blends; polyvinyl chloride/polyethylene; polyvinyl chloride/chlorinated polyethylene and others.

The primary requirement for the substantially thermoplastic polymeric material is that it retain sufficient thermoplastic properties to permit melt blending with wood fiber, permit formation of linear extrudate pellets, and to permit the composition material or pellet to be extruded or injection molded. Useful PVC resin blends (including foaming agent and stabilizers) and extrusion conditions therefore are described by Suzuki et al. in U.S. Patent No. 5,712,319 the disclosure of which is hereby incorporated by reference.

A variety of biofiber materials can be used in the composites of the invention. Such fibers are fibers of naturally occurring sources that have significant aspect ratio to provide structural properties of the composite. Such fibers include wood fiber, flax, cotton, bagasse, wood flour, straw, recycled fiber, pulp, or other cellulosic material, etc. Wood fiber, in terms of abundance and suitability can be derived from either soft woods or evergreens or from hard woods commonly known as broad leaf deciduous trees. Soft woods are generally preferred for fiber manufacture because the resulting fibers are longer, contain high percentages of lignin and lower percentages of hemicellulose than hard woods. While soft wood is a primary source of fiber for the invention, additional fiber make-up can be derived

from a number of secondary or fiber reclaim sources including bamboo, flax, rice, sugar cane, and recycled fibers from newspapers, boxes, computer printouts, etc.

However, the primary source for wood fiber includes the wood fiber by-product of sawing or milling soft woods commonly known as sawdust or milling tailings. Such wood fiber has a regular reproducible shape and aspect ratio. The fibers based on a random selection of 100 fibers are commonly at 0.1 to 3 mm in length, 0.05 to 1 mm in thickness and commonly have an aspect ratio of at least 1.8, or 2.5 to 7.0. The preferred fiber is derived from processes common in the manufacture of windows and doors. Wooden members are commonly ripped or sawed to size in a cross grain direction to form appropriate lengths and widths of wood materials. The by-product of such sawing operations is a substantial quantity of sawdust. In shaping a regular shaped piece of wood into a useful milled shape, wood is passed through machines which selectively removes wood from the piece leaving the useful shape. Such milling operations produce substantial quantities of sawdust or mill tailing by-products. Furthermore, substantial waste trim is produced when shaped materials are cut to size and subsequently have mitered joints, butt joints, overlapping joints, mortise and tenon joints formed therein. Such process produce large trim pieces which can comminuted by well-known methods to form wood fiber having dimensions approximating sawdust or mill tailings. Blending of wood fibers with other biofibers (all of which may have different particle sizes and particle size distributions) is envisioned. Alternatively, the fiber stream can be pre-sized, or can be sized after blending, to yield input fiber have a preferred size and size distribution. Finally, the fiber can be pre-pelletized before use in composite manufacture.

Frequently the waste trim pieces and sawdust material contains substantial proportions of other materials used to make wood sashes and frames for windows and doors including, but not limited to, for example, polyvinyl chloride or other polymer materials that have been used as coating, cladding or envelope on wooden members (10 wt %); recycled structural members made from thermoplastic materials; polymeric materials from coatings; adhesive components in the form of hot melt adhesives, solvent based adhesives, powdered adhesives, etc.; paints including water based paints, alkyd paints, epoxy paints, etc.; preservatives, anti-

fungal agents, anti-bacterial agents, insecticides, etc., and other non-wood materials (ONWM) used in the manufacture of wooden doors and windows. The ONWM content is less than 25 wt-% of the total biofiber input into a preferred polyvinyl chloride wood fiber product. The intentional recycle ranges from 1 to 25 wt-% or 2 to 20 wt-% or 3 to 15 wt-% recyclable ONWM based on the weight of input biofiber.

In manufacturing the thermoplastic-biofiber composite, the thermoplastic and fiber are blended, often in dry form, and then introduced into an extruder in which the materials are intimately blended, melted and formed into a composite material as described in greater detail hereinbelow. Often, the structural components are directly extruded from the initial blending of these materials or can be first extruded in the form of a pellet which then can be introduced, in turn, into a profile forming extruder device at a later time or different location.

The thermoplastic resin and biofiber can be combined and formed into a pellet using thermoplastic extrusion processes. Fiber can be introduced into pellet making process in a number of sizes. The biofiber (when wood fiber) should have a minimum length of at least 0.1 mm because wood flour tends to be explosive at certain wood to air ratios. Further, wood fiber of appropriate size of an aspect ratio greater than 1, or greater than 2, tends to increase the physical properties of the extruded structural member. However, useful structural members can be made with a fiber of very large size. Fibers that are of reinforcing length up to 3 cm in length and 0.5 cm in thickness can be used as input to the pellet or linear extrudate manufacturing process. However, particles of this size do not produce highest quality structural members or maximized structural strength. The best appearing product with maximized structural properties are manufactured within a range of particle size as set forth below. Further, large particle wood fiber an be reduced in size by grinding and screening sifting or other similar processes that produce a fiber similar to sawdust having the stated dimensions and aspect ratio. One further advantage of manufacturing sawdust of the desired size is that the material can be pre-dried before introduction into the pellet or linear extrudate manufacturing process. Further, the wood fiber can be pre-pelletized into pellets of wood fiber with small amounts of binder if necessary.

During the pelletizing process for the composite pellet, the thermoplastic resin and fiber are intimately contacted at high temperatures and pressures to insure that the fiber and polymeric material are wetted, mixed and extruded in a form such that the polymer material, on a microscopic basis, coats and flows into the pores, cavity, etc., of the fibers. During the extrusion process, the fibers are substantially longitudinally oriented into the extrusion direction by the extrudate flow profile. Such substantial orientation causes overlapping of adjacent parallel fibers and polymeric coating of the oriented fibers resulting a reinforced material that has substantially improved mechanical properties such as tensile strength, coefficient of thermal expansion, and a modulus of elasticity.

Moisture control is an element of manufacturing a useful linear extrudate or pellet. Depending on the equipment used and processing conditions, control of the water content of the linear extrudate or pellet can be important in forming a successful structural member substantially free of internal voids or surface blemishes. The concentration of water present in the biofiber during the formation of pellet or linear extrudate when heated can flash from the surface of the newly extruded structural member and can come as a result of a rapid volatilization, form a steam bubble deep in the interior of the extruded member which can pass from the interior through the hot thermoplastic extrudate leaving a substantial flaw. In a similar fashion, surface water can bubble and leave cracks, bubbles or other surface flaws in the extruded profile or member. Fiber sources when harvested, depending on relative humidity and season, can contain from 30 to 300 wt-% water based on fiber content. After cutting and drying the fiber can have a water content of from 20 to 30 wt-%. Because of the variation in water content of fiber source and the sensitivity of extrudate to water content, the control of water to a level of less than 8 wt-% in the pellet, based on pellet weight, is important.

When a structural member, such as the siding, or siding profile is extruded in a non-vented extrusion process, pellets should be as dry as possible and have a water content between 0.01 and 5 wt-%, or less than 3.5 wt-%. When using vented equipment in manufacturing the extruded linear member, a water content of less than 8 wt-% can be tolerated.

The pellets or linear extrudate are made by extrusion of the resin and fiber composite through an extrusion die resulting in a linear extrudate that can be cut into a pellet shape. The pellet cross-section can be any arbitrary shape depending on the extrusion die geometry. However, a regular geometric cross-sectional shape can be useful. Such regular cross-sectional shapes include a triangle, a square, a rectangle, a hexagonal, an oval, a circle, etc. The preferred shape of the pellet is a regular cylinder having a roughly circular or somewhat oval cross-section. The pellet volume is preferably greater than about 12 mm^3. The preferred pellet is a right circular cylinder, the preferred radius of the cylinder is at least 1.5 mm with a length of at least 1 mm. Preferably, the pellet has a radius of 1 to 5 mm and a length of 1 to 10 mm. Most preferably, the cylinder has a radius of 2.3 to 2.6 mm, a length of 2.4 to 4.7 mm, a volume of 40 to 100 mm^3, a weight of 40 to 130 mg and a bulk density of about 0.2 to 0.8 gm/mm^3.

The interaction, on a microscopic level, between the resin, polymer mass and the fiber is an important element. The physical properties of an extruded member are improved when the polymer melt, during extrusion of the pellet or linear member, thoroughly wets and penetrates the wood fiber particles. The thermoplastic material includes an exterior continuous organic polymer phase with the biofiber particle dispersed as a discontinuous phase in the continuous polymer phase. The material during mixing and extrusion obtains an aspect ratio of at least 1.1 or between 2 and 10, optimizes orientation such as at least 20 wt-% or 30% of the fibers are oriented in an extruder direction, and are thoroughly mixed and wetted by the polymer such that the exterior surfaces of the wood fiber are in contact with the polymer material. This means, that pores, crevices, cracks, passageways, indentations, etc., are filled by thermoplastic material. Such penetration is attained by ensuring that the viscosity of the polymer melt is reduced by operating at elevated temperature and using sufficient pressure to force the polymer into accessible internal pores, cracks and crevices within the biofiber in addition to filling like features on the biofiber surface.

During the pellet or linear extrudate manufacture, substantial work is done in providing a uniform dispersion of the fiber into the fluidized polymer. Such work produces a substantial number of orientable, acicular fiber particles. Such

particles are easily oriented into the extrusion direction by the flow field of the extrusion process resulting in extrusion of parts having improved structural properties.

The pellet dimensions are selected for both convenience in manufacturing and in optimizing the final properties the extruded materials. A pellet is with dimensions substantially less than the dimensions set forth above difficult to extrude, pelletize and handle in storage. Pellets larger than the range recited are difficult to introduce into extrusion or injection molding equipment, and are difficult to melt and form into a finished structural member, such as siding, profile or siding profile.

Thermoplastic polymer-biofiber composite material used to produce the siding profile is made under high shear conditions that are conducive to achieving intimate contact between polymer and fiber that result in the unique physical and mechanical properties exhibited in structural parts made from the composite. Appropriate high shear conditions can be produced in a variety of powder blenders and mixers. For example Nishibori uses a blade mixer (U.S. Patent No. 5,725,939) in tandem with an extruder to produce biofiber composite sheet materials. Screw mixers, especially extruders, are preferred processors ideally suited for cascading continuous chemical process unit operations such as heating, mixing, and devolatizing for example. Because small, controlled volumes of material sequentially pass through isolated zones along the screw(s), process parameters can be continuously monitored and adjusted using microprocessors. Therefore, a preferred process is the Krupp Werner & Pfleiderer (W & P) *KombiPlast* process wherein a co-rotating, twin screw extruder is used to make composite that is delivered to a single screw extruder operating in tandem where composite is further heated and compressed prior to delivery to an extrusion die. The die can be either a profile die for direct extrusion of the inventive siding unit, siding profile or pellet die.

The process steps used to make the thermoplastic-biofiber composite in a screw mixer generally begin with a fiber drying step wherein biofiber is conductively heated under mild shear conditions and the steam generated is vented from the mixer. Temperature, heat transfer, and shear are closely controlled to

optimize moisture vaporization to avoid fiber scorching, breaking, and geysering at the vent (at high moisture levels the steam generated blows fiber out the vent in geyser like fashion). If it is necessary to cushion the fiber during drying part or the entire thermoplastic can be added with the fiber during the drying step. Fiber moisture is preferably reduced to between 3 and 5 wt % during drying. Thermoplastic and optional regrind material is added to dried fiber at pre-selected point down the screw.

A "stuffer" screw may be used to add the thermoplastic depending on the pressure in the barrel at the addition point, which is related to the material throughput rate and compression. The proto-composite is mixed and heated to distribute thermoplastic throughout the fiber stream. Further downstream kneading blocks shear and mixes the composite. At this point, the thermoplastic melts (polyolefins) or fluxes (PVC) to form a fluid mass capable of forming a melt seal in the extruder. The temperature at this point can be 195 –215 degrees C for PVC composites. The fluid composite then passes through a high free volume vacuum devolatization zone operating at a vacuum of sufficient strength to remove volatile products from the composite but of insufficient strength to pull the composite apart (for example, a negative pressure of from 50 to 90 kilopascals). During devolatization the compressed composite abruptly expands and cools by as much as 10°C such that any thermal decomposition initiated during high shear mixing is quenched. Expanding volatile products vented through a vacuum port include, for example, steam, terpenes, lubricants, stabilizers, and small amounts of hydrogen chloride (when PVC comprises the thermoplastic). The expanded composite is recompressed to further intimate contact between fiber and thermoplastic before it is discharged into an evacuated transition box between the twin and single screw extruders. Upon entering the transition box, the composite now free of the confines of the extruder screw(s) is free to expand and cool in three dimensions. This expansion is sufficiently violent that some of the remaining, unruptured biofiber cells that have become steam filled during processing explode thus opening their interior volumes for subsequent introduction of fluxed polymer. Newly formed volatile products are evacuated at negative pressure in the range of from 50 to 95 kilopascals. Upon entering the single screw extruder, the composite is compressed

and heated to a pressure and temperature dictated by operating requirements of the extrusion die. Optional materials can be added to the composite at pre-selected points along the single screw.

When the composite is directly extruded through a profile die to form the inventive siding siding profile, the die may be optionally adapted to co-extrude capstock(s) on predetermined areas of the extruded profile external surface. Such capstocks include, but are not limited to, colored materials that enhance weatherability, abrasion resistant coatings, and the like.

Thermoplastic polymer-biofiber composite material is visco-elastic. Upon exiting the die, the hot extruded part is more a viscous fluid than an elastic solid. Post extrusion cooling and shaping process are applied to the part as it transforms to become more an elastic solid than a viscous fluid as it cools to ambient temperature. Therefore, the temperature, draw down, and cooling rate of the extruded part are controlled to minimize the residual stress in the finished part. Such "frozen in" stresses gradually relax over time at different rates that depend on the temperature of the end use environment. This stress relaxation can cause a retinue of mechanical problems for structures constructed from the extrude parts (profiles). Post extrusion cooling and shaping (calibrating) processes and apparatus are described by Purstinger, U.S. Patent No. 5,514,325; DeCoursey et al., U.S. Patent No. 5,008,051; and Groeblacher, U.S. Patents Nos. 5,578,328 & 5,484,577 the disclosures of which are hereby incorporated by reference.

When the composite is extruded through a stranding die to form pellets, the pressure, temperature, and cutter rotation speed are adjusted to optimize pellet uniformity and density. Pelletizing the composite permits decoupling of the composite making and extrusion processes. Pellets can be extruded as described above for the single screw portion of the W&P *KombiPlast* process, but pellets are preferably extruded using counter-rotating, twin screw extruders like the Cincinnati-Milicron CM-80, for example, that develop high die head pressures at low screw rotation speeds. Composite foaming, capstock co-extrusion, and down stream profile cooling and calibration processes are identical to those for direct profile extrusion described above.

In a variation of the process disclosed above, biofiber can be dried, thermoplastic can be melted or fluxed, and the fiber and plastic then mixed together in separate extruders. Such multi-extruder processes permit more precise control of the heat transfer during heating and the shear during mixing. Such an approach reduces the stress and comminution of acicular fiber particles that degrades the particle size distribution of the fiber and mechanical properties of structures made from the composite.

The high throughput process used to make thermoplastic-biofiber composite operate at a rate of at mass flow rates in the range of from 10 to 5000 kg-hr^{-1} and are capable of efficiently converting the maximum available mechanical energy supplied by blade and/or screw mixers into composite. However, the densification process further requires delivery of this energy at a rate sufficient to overcome the energy barriers opposing densification. Therefore the energy delivery of the process occurs at a shear rate and for a time sufficient to force thermoplastic into the biofiber cell interior without breaking acicular fibers (or otherwise commuting/ degrading the biofiber size distribution). The desired composite morphology is one where the fibers are surrounded and filled with thermoplastic to form a dense void free material as opposed a porous, unfilled structure of collapsed fibers that is to be avoided.

During extrusion of fluid composite through a profile die, the torque exerted on acicular fibers by shear gradients tend to rotate them in the flow direction thus producing a more aligned morphology that generally improves the mechanical properties of the resulting profile, the torque can easily exceed that required to break the fiber. Therefore, when the input fiber is highly acicular the shear rate, and/or the time spent by the material, in high shear parts of the process are minimized to prevent excessive particle breakage.

The versatility of W & P co-rotating, fully intermeshing twin screw extruders used in the *KombiPlast* process is described in greater detail by Marten et al. in U.S. Patent No. 5,051,222. The screw is designed in a segmented fashion so that a variety of different screw elements can be placed on keyed shafts to achieve the desired degree of mixing for a particular application. Screw elements can vary along the length of the screw, but the two screws must be matched to achieve fully

intermeshing surfaces. Generally speaking there are two different types of elements, screw conveying elements and kneading or mixing disks. The screw elements can have either a forward or reverse pitch, while the kneading disks can have a neutral pitch in addition to the forward or reverse pitch. The kneading disks consist of staggered elliptical disks that are offset to achieve an overall conveying pitch. The disks can vary in width from one element to another but are typically of uniform width within an element. In addition to a varied pitch in the kneading blocks, different screw elements can have different conveying pitches.

As can be expected, all of the elements impart different levels of shear history and conveying ability. These can be summarized in the following list of elements and their relative shear intensity:

Greatest Shear--Least Forward Conveying Efficiency
- reverse pitch screw elements
- reverse pitch kneading blocks
- neutral kneading blocks
- forward pitch kneading blocks
- forward pitch screw elements

Least Shear--Most Forward Conveying Efficiency

In addition, wider kneading blocks impart more shear to the melt. Also tighter pitch imparts more shear. A worker skilled in the art can combine all of these factors to design a screw that achieves the required balance between shear input and conveying efficiency as material moves along the screw without thermally or mechanically degrading the composite material as it forms.

In co-rotating twin-screw extruders the shear rate and residence time spent by extrudate in the high shear (generally the kneading) zones of the extruder is a complex interactive function of screw rotation speed (RPM) and extruder screw/barrel geometry. However, the following general observations are relevant:

For a given geometry the shear rate increases in direct proportion to screw speed and narrowing of the clearance between the tips of various screw elements and the extruder barrel (affected by the degree of wear);

The residence time spent by the extrudate in the high shear zone is determined by the degree of fill of the extruder screw and the following interactive geometrical factors: 1) the width of the narrow clearance zone (the number and width of kneading block elements used in the screw design), 2.) the number of lobes

on the screw elements--(increasing number of lobes increases the volume of material in the narrow clearance zone while simultaneously reducing the free volume of lower shear zone between the tip and root of the screw element); and 3.) the number and type of reverse (left-handed) elements included in the screw design). Suitable extruders useful for making thermoplastic polymer-biofiber composite material are available from Krupp Werner Pfleiderer, Leistritz, Davis Standard, and Entek Manufacturing, Inc.

The thermoplastic-biofiber composite siding profile can be manufactured with an additional surface layer, protective coating, capstock layer on any surface, or portion thereof on the exterior or interior of the siding profile. The coating, layer, or capstock can provide environmental stability, wear resistance, resistance to environmental moisture, stability to ultraviolet light or any other physical or chemical property that can tend to improve the wear ability or lifetime of any aspect of the siding profile. Extruded capstock materials are known for use in the formation of extruded profile materials. Coextruding a layer of an acrylic, a chloropolymer, a fluoropolymer, or other blended polymeric material that can maintain the surface quality of the profile typically makes an effective protective layer. A representative abrasion resistant coating is LUCITE® TufCoat 4600, available from ICI Acrylics, Memphis, TN. Capstocks can have a clear, colored or patterned appearance. The colors can be formed by the addition of dyes and/or pigments to the capstock layer to form a green, Terratone, white, or other colored appearance. Further, the capstock can take the appearance of a wood grain, a stone-like appearance or other natural surface quality. Such capstock layers are manufactured by coating, painting or coextruding the thermoplastic material in a thin layer onto the siding profile during the extrusion of the siding profile. During extrusion, the capstock layer is carefully gauged in thickness to conserve material but to provide an excellent surface and acceptable appearance (less than two millimeters, or less than 1 millimeter). Typical properties of a thermoplastic-biofiber composite materials formed from compositions comprising approximately 60 wt. % PVC, 40 wt % wood fiber (PVC) and 30 wt % polypropylene, 70 wt. % wood fiber (PP) are shown in Table -1 Example 1.

2-Part Siding Unit Manufacture

The 2-part siding unit is formed by securing the siding profile to upper flange. As described above, the siding profile and the upper flange can be formed separately by extrusion. The siding profile can be formed before or after the upper flange is formed. If the upper flange is formed before the siding profile, the upper flange can be secured to the siding profile as the siding profile is being manufactured.

The 2-part siding unit can be manufactured with tight tolerances. The upper flange and siding profile can be aligned to maintain an overall manufacturing tolerance that is less than the manufacturing tolerance of the upper flange added to the manufacturing tolerance of the siding profile. This is due to the overlapping of the upper flange and siding profile. Thus, the formation of the upper flange and siding profile can be preformed under easier tolerances. The easier tolerances allow the upper flange and main body to be manufactured quickly and economically. A subsequent alignment step maintains the tight overall manufacturing tolerances necessary for manufacturing a consistent siding product.

After the upper flange and siding profile are aligned, the upper flange and siding profile are secured together. The upper flange and siding profile can be secured with, for example, an adhesive, thermal or ultrasonic welding. Energy directors may be used to aid in the fastening as described above.

After the upper flange and siding profile are secured together forming the 2-part siding unit, the 2-part siding unit is cut to a desired length. The 2-part siding unit can be cut to lengths that are longer than the 12 foot lengths vinyl siding is cut to. The 2-part siding can be cut to lengths of 5 meters (16 feet) or greater. The whole manufacturing process or portion thereof can be portable and operated at the installation site to provide 2-part siding lengths that are cut to exact lengths needed for the particular installation.

2-Part Siding Mechanical Properties

The Young's modulus of the siding profile in the extrusion direction can be at least 500,000 psi, 800,000 psi or 1,000,000 psi as measured by ASTM D3039. The Flexural Modulus of the siding profile can be at least 500,000 psi as measured by ASTM D790.

The Young's modulus of the upper flange profile in the extrusion direction should be about at least 100,000 psi, 300,000 psi or 500,000 as measured by ASTM D3039. The Flexural Modulus of the upper flange can be at least 400,000 psi as measured by ASTM D790.

2-Part Siding Thermal Properties

The Coefficient of Thermal Expansion (COTE) of the thermoplastic polymer-biofiber composite materials can range from 4.5 x 10^{-5} m/m/°C (2.5 x 10^{-5} in/in/°F) to 3 x 10^{-5} m/m/°C (1 x 10^{-5} in/in/°F) and all numerical values subsumed therein. The Heat Deflection Temperature is the temperature at which a standard test bar deflects a specified amount under a stated load. The PVC containing composite used in the invention has a Heat Deflection Temperature of 78 degrees Celsius at 1.82 megapascals and a Heat Deflection Temperature of 105 degrees Celsius at 0.46 megapascals as measured by ASTM D648. The flash ignition temperature is the minimum temperature at which sufficient flammable gas is emitted to ignite momentarily upon application of a small external pilot flame. The Flash Ignition Temperature of the PVC composite is 410 degrees Celsius as measured by ASTM D1929. The Self-Ignition Temperature is the minimum temperature at which the specimen spontaneously ignites in the absence of a flame ignition source. The Self-Ignition Temperature of the PVC composite is 425 degrees Celsius as measured by ASTM D1929. The Flame Spread Index is the a number or classification indicating a comparative measure of surface burning behavior derived from observations made during the progress of the boundary of a zone of flame under defined test conditions. The Flame Spread Index of the PVC composite is 10 as measured by ASTM E84. The Average Flame Spread Index is a number indicating a comparative measure of surface flammability of materials using a radiant heat source under defined test conditions. The Average Flame Spread Index of the PVC composite is 22.7 as measured by ASTM E162.

Installation of the Siding System

The siding system of the invention can be assembled with a variety of known mechanical fastener techniques. Such techniques include staples, screws, nails, and other hardware.

The low coefficient of thermal expansion and structural strength of the thermoplastic polymer-biofiber composites, when coupled with partitioning of potential buckleing inducing length changes obtained be fixedly attaching the siding panel to the substrate, permits use very long length planks. The 2-part siding unit may be "hard nailed" in the center of the 2-part siding unit length. This allows for expansion and contraction to occur in both horizontal directions from the center of the 2-part siding unit. The remaining fasteners may be "loose nailed" allowing horizontal movement along the 2-part siding unit.

The 2-part siding units can be made a fixed length shorter than the width of a side of most houses, and thus it is necessary to butt, splice or join two 2-part siding units together at their ends. Each 2-part siding unit may have a nominal length of 16 feet, with an actual length of 16 feet, 4 inches. With respect to the vertical siding designs, the length may be 12 feet. Adjacent 2-part siding units are connected end-to-end with a butt joint, and there is no overlapping of the siding units with this type of connection. The ends of each siding unit may be mitered to have a beveled interconnection surface. Components of the system can also be joined by use of: glue, or a melt fusing technique wherein a fused weld forms a joint between two 2-part siding units, or the 2-part siding units can be joined by splines adapted to fit with the interior structure of the siding unit. Such joints can be bonded using a spline placed into the profile that is hidden when joinery is complete. Such a spline can be adhesively attached, thermally welded, heat staked into place or mechanically fastened. The butt-joint may also be formed by frictional engagement or mechanical interlock. The spline can be injection molded or formed from similar thermoplastics and can have a service adapted for compression fitting and secure attachment to the structural member of the invention. Such a spline can project from 1 to 12 inches into the interior of the siding unit.

Further, components of the siding system can be assembled by gluing components together with a solvent, structural or hot melt adhesive. Solvent borne adhesives that can act to dissolve or soften thermoplastic present in the components and to promote solvent based adhesion or welding of the materials. In the welding technique, once the joint surfaces are formed, the surfaces of the joint can be heated to a temperature above the melting point of the composite material and while hot,

the mating surfaces can be contacted in a configuration required in the assembled structure. The contacted heated surfaces fuse through an intimate mixing of molten thermoplastic from each surface. Once mixed, the materials cool to form a structural joint having strength typically greater than joinery made with conventional techniques. Any excess thermoplastic melt that is forced from the joint area by pressure in assembling the surfaces can be removed using a heated surface, mechanical routing, or a precision knife cutter.

Using these general assembly techniques, the siding system of the invention is typically constructed by installing siding units on a support surface. Such support surfaces can often comprise a concrete surface, wood framing, I-beam joist framing, plywood on a frame support or any other suitable contact surface. The siding unit is often cut to appropriate length and laid on the surface.

EXAMPLES

Example 1

Table 1 below show various physical properties of two thermoplastic-biofiber composite material siding profiles. The first composite is a PVC-biofiber composite that contains 60 wt.% polyvinyl chloride (PVC) and 40 wt.% wood fiber made by the extrusion process detailed above. The second composite is a PP-biofiber composite that contains 30 wt.% polypropylene (PP) and 70 wt.% wood fiber made by the extrusion process detailed above.

Table 1. Thermoplastic-Biofiber Composites

Measurement	ASTM Method	Units	PVC-Biofiber Composite	PP-Biofiber Composite
Tensile Modulus	D3039	psi(MPa)	950,000 (6,500)	850,000 (5,585)
Tensile Strenght	D3039	psi(MPa)	5,500 (38)	5,750 (40)
Tensile % Strain	D3039	%	1	4
Flexural	D790	psi(MPa)	830,000 (5,700)	657,000 (4,530)

Measurement	ASTM Method	Units	PVC-Biofiber Composite	PP-Biofiber Composite
Modulus				
Modulus of Rupture	D790	psi(MPa)	10,000 (69)	10,000 (69)
Izod Notched Impact	D256	in-lb/in (J/m)	7 (370)	16 (846)
Specific Gravity	D792	g/cm^3	1.4	1.23
HDT (264 psi)	D648	°F(°C)	173 (78)	306 (152)
COTE	D696	in/in/°F	1.6 x 10^{-5}	1.3 x 10^{-5}

Example 2

Table 2 below shows various physical properties of materials that can be used to form the siding profile. Lengths of the siding were manufactured and tested for coefficient of thermal expansion, thermal conductivity, decay, corrosion, heat distortion temperature, water absorption, moisture expansion, and compression load. For many of these characteristics, the composite siding of the present invention was compared to siding manufactured with conventional siding materials. Table 2 displays the test data developed in these experiments and obtained from published sources. The material of the preferred siding unit is indicated by the designation "Biofiber-Thermoplastic" in the Examples below. This "Biofiber-Thermoplastic" composite material is the material described above, made of 60 wt-% polyvinyl chloride and 40 wt-% fiber derived from a soft wood.

Using the methods for manufacturing a pellet and extruding the pellet, a siding member as illustrated in Figures 6A-D was manufactured using an appropriate extruder die. The melt temperature of the input to the machine was 390°-420°F. A vacuum was pulled on the melt mass of no less that 3 inches mercury. The overall width of the siding profile was 6 inches. The wall thickness of any of the elements of the extrudate was about 0.1 inch.

Several different siding materials were tested and/or analyzed, as shown in the tables below. The data for the five types of siding materials, other than the composite material, was obtained from published sources. For aluminum, the data was obtained from *Metals Handbook*, Vol. 2, 9th Ed., American Society for Metals, 1990. For PVC, the data was obtained from the specifications and product literature for PVC siding which is manufactured by Reynolds Metals Company of Richmond, Virginia. For cedar, the data was obtained from *Forest Products and Wood Science*, J.G. Haygreen and J.L. Bowyer, The Iowa State University Press, 1982. For Masonite™, the data was obtained from the specifications and product literature for Masonite siding obtained from Masonite Corporation of Chicago, Illinois. (The Masonite material is a fiber board material made from hard wood fibers and cement binders.) The data for steel was obtained from *Metals Handbook*, Vol. 1, 9th Ed., American Society for Metals, 1990.

The determination of the dent resistance of impact of the siding profiles by a falling mass was determined by the following procedure. This procedure is a modification of the CEN/TC33 "European Standard Method for the determination of the resistance to impact by a falling mass at about 21.1°C (70°F) of unplasticized polyvinyl chloride (PVC-U) siding profiles used in the fabrication of windows and doors for the assessment of physical properties of the extrusion piece. Eighteen inch length test pieces (about 48.5 centimeters) were cut from lengths of siding profiles and were subjected to a blow from a mass falling from a known height on the surface of the profile at a point midway between two supporting webs at a fixed width and at a fixed temperature. After testing, the profiles are visually examined for failures which appear at the point of impact. Siding profile typically refers to an extruded piece having load bearing functions in a construction such as a window or door. The test surface, sight surface or face surface of the profile is a surface exposed to view when the window is closed. The falling weight impacts the face surface, sight surface or exposed surface. A web typically refers to a membrane which can be rigid or non-rigid connecting two walls of the siding profile. The impact testing machine apparatus incorporates the following basic components. The main frame is rigidly fixed in a vertical position. Guide rails fixed to the main frame accommodate the falling mass and allow it to fall freely in the vertical plane directly

impacting the face surface or the sight surface of the test profile. The test piece support consists of a rounded off support member with a distance between 200 ± 1 millimeters. The support is made from steel and rigidly fixed in a solid foundation or on a table with a mass of more than 50 kilograms for stability. A release mechanism is installed such that the falling mass can fall through a height which can be adjusted between 1500 ± 10 millimeters measured from a top surface of the test piece to the bottom surface of the falling mass. The falling mass is selected having 1000 ± 5 grams. The falling mass has a hemispherical striking surface that contacts the face surface of the profile. The hemispherical striking surface has a radius of about 25 ± 0.5 millimeters. The striking surface of the falling mass shall be smooth and conform to the hemispherical striking shape without the imperfections that could cause damage resulting from effects other than impact. One or more test pieces were made by sawing appropriate lengths from typical production profile extrusion pieces. The test pieces were conditioned at a temperature of about 21.1 ± 0.2°C for at least one hour prior to testing. Each test piece was tested within 10 seconds of removal from the conditioning chamber to ensure that the temperature of the piece did not change substantially. The profile was exposed to the impact from the falling mass onto the sight surface, face surface or exposed surface of the profile. Such a surface is the surface designed to be exposed to the weather. The falling mass is dropped directly onto the sight surface at a point midway between the supporting webs. The profile is to be adjusted with respect to the falling mass such that the falling mass strikes in a direction normal to the surface of the test face. The results of the testing are shown by tabulating the number of test pieces tested, the number of pieces broken or if not broken, the depth of any defect produced in the profile by the test mass.

Table 2. Siding Material

Material	COTE in/in/F° x10⁻⁶	Thermal Conductivity W/mK	Decay	Corrosion	HDT	Water Absorption	Standards	Ref.	Dent Resistance Testing*
Biofiber-Thermoplastic	10 to 20	0.17	N/A	N/A	200°F	0.90%	Yes	1	-0.0070
Aluminum	12.1	173	N/A	Yes	N/A	N/A	Yes	2	**
PVC	36	0.11	N/A	N/A	170°F	N/A	Yes	3	-0.0650
Cedar	3 to 5	0.09	Yes	N/A	N/A	Yes	Yes	4	-0.0630
Masonite	N/A	N/A	Yes	N/A	N/A	12%	Yes	5	-0.0025
Steel	12	59.5	N/A	Yes	N/A	N/A	Yes	6	-0.0315

* Values obtained from testing performed at Aspen Research Corporation
** Value for interval could not be measured due to surface deformation
1. Fibrex Design Manual and Aspen Research Corp. test reports
2. Metals Handbook Vol. 29th Edition.
3. Specifications for Reynolds Siding - values obtained from product literature
4. Forest Products and Wood Science, JG Haygreen and JL Boyer, 1982 The Iowa State University Press
5. Masonite product literature
6. Metals Handbook Vol. 19th Edition.

Explanation of N/A status:
Decay: The N/A status indicates the material is not subject to decay because there is no biological mechanism to indicate decay
Corrosion: The N/A status indicates no mechanism in the material to promote corrosion
HDT (heat distortion temperature): The metals do not distort until an extremely high temperature which is outside the range of what siding would experience; therefore, not applicable. The N/A values for Masonite indicate that the value was not available.
Water Absorption: The metals do not take up water; hence, the N/A status. The PVC value is low enough to be considered to be negligible.
ASTM Test Methods
COTE D696 - for Composite and PVC
Thermal Conductivity F433 - for Composite and PVC
HDT (heat distortion temperature) D648 for Composite and PVC
Moisture Absorption D570-84 for Composite and PVC

Example 3

Table 3 shows the failure energy for various invention embodiments. Each embodiment was tested as installed on a building substrate. The embodiments were tested by striking the siding profile at the point most susceptible to impact failure. All 2-part siding units had a PVC upper flange.

The PVC-biofiber siding profile contained 60 wt.% PVC and 40 wt.% wood fiber formed by the process discussed above.

Table 3. 2-Part siding unit Failure Energy

Embodiment (Refer to Figures)	Warm 65°F (in-lbs)	Cold 15°F (in-lbs)
Figure 6A-C PVC-biofiber (Hollow)	3	3
Figure 1A-C PVC-biofiber	56	51

The failure energy measurements were made in accord with ASTM D5420 (Gardner Impact). An instrumented impacter (equipped with an accelerometer) having a mass of 2 pounds and a contact diameter of 2.2 inches was used in this modified Gardner Impact Test.

The various embodiments described above are provided by way of illustration only and should not be construed to limit the invention. Those skilled in the art to which the invention most closely pertains will readily recognize various modifications and changes that may be made to the present invention without strictly following the exemplary embodiments and applications illustrated and described herein, and without departing from the true scope of the present invention that is set forth in the following claims.

WE CLAIM:

1. A siding unit, comprising:
   (a) a siding profile made of a thermoplastic-biofiber composite material; and
   (b) an upper flange fastened to the siding profile where the upper flange is made of a thermoplastic polymer.

2. The siding unit of claim 1, wherein the siding profile comprises 50 to 90 parts of biofiber and 10 to 50 parts of polymer per 100 parts of thermoplastic-biofiber composite material.

3. The siding unit of claim 1, wherein the upper flange comprises polyvinyl chloride.

4. The siding unit of claim 1, wherein the siding profile has a coefficient of thermal expansion less than a coefficient of thermal expansion of the upper flange.

5. The siding unit of claim 4, wherein the upper flange coefficient of thermal expansion is at least 1.5 times the siding profile coefficient of thermal expansion.

6. The siding unit of claim 4, wherein the upper flange coefficient of thermal expansion is at least 2 times the siding profile coefficient of thermal expansion.

7. The siding unit of claim 4, wherein the siding profile coefficient of thermal expansion is less than 4.5×10^{-5} m/m/°C (2.5×10^{-5} in/in/°F).

8. The siding unit of claim 4, wherein the upper flange coefficient of thermal expansion is more than 4.5×10^{-5} m/m/°C (2.5×10^{-5} in/in/°F).

9. The siding unit of claim 7, wherein the siding profile coefficient of thermal expansion is 3×10^{-5} m/m/°C (1×10^{-5} in/in/°F).

10. The siding unit of claim 8, wherein the upper flange coefficient of thermal expansion is 6×10^{-5} m/m/°C (3.4×10^{-5} in/in/°F).

11. The siding unit of claim 1, wherein at least a portion of the upper flange is overlapping the siding profile.

12. The siding unit of claim 11, wherein the upper flange is fastened to the siding profile by an ultrasonic or thermal weld.

13. The siding unit of claim 1, further including means for supporting the siding profile or a second siding profile substantially parallel to the siding profile and overlapping the upper flange.

14. The siding unit of claim 13, wherein the means for supporting the siding profile includes a projection on an inner surface of the siding profile.

15. The siding unit of claim 14, wherein the projection is made of a thermoplastic-biofiber composite material, a thermoplastic material or a foam.

16. The siding unit of claim 14, wherein the projection is made of a porous thermoplastic-biofiber composite material.

17. The siding unit of claim 13, wherein the means for supporting the second siding profile substantially parallel to the siding profile and overlapping the upper flange includes a fin integral with the upper flange and distal to the siding profile.

18. The siding unit of claim 13, wherein the means for supporting the second siding profile substantially parallel to the siding profile and overlapping the upper flange includes an arch integral with the upper flange and distal to the siding profile.

19. The siding unit of claim 17, wherein the fin is made of a thermoplastic-biofiber composite material, a thermoplastic material or a foam.

20. The siding unit of claim 18, wherein the arch is made of a thermoplastic-biofiber composite material, a thermoplastic material or a foam.

21. The siding unit of claim 1, wherein the siding profile includes an inner surface and an outer surface defining a cavity.

22. The siding unit of claim 21, wherein at least a portion of the cavity comprises a porous thermoplastic-biofiber composite material or a foam.

23. The siding unit of claim 1, wherein the siding profile is a solid member.

24. The siding unit of claim 22, wherein the siding profile has a thickness of 2.5 mm (0.10 in) to 3.8 mm (0.15 in).

25. The siding unit of claim 23, wherein the siding profile has a thickness of 3.2 mm (0.12 in).

26. The siding unit of claim 1, wherein the siding profile includes a layer of capstock over at least a portion of the siding profile.

27. The siding unit of claim 1, wherein the upper flange includes a plurality of elongated slots in an offset vertical relation.

28. The siding unit of claim 1, wherein the siding profile is a single-face profile.

29. The siding unit of claim 1, wherein the siding profile is a double-face profile.

30. The siding unit of claim 1, wherein an outer surface of the siding profile is convex.

31. The siding unit of claim 1, wherein an outer surface of the siding profile is planar.

32. A siding assembly for attachment to a building substrate, comprising:

(a) a plurality of siding units, each siding unit having:

(i) a siding profile made of a thermoplastic-biofiber composite material;

(ii) an upper flange fastened to the siding profile where the upper flange is made of a thermoplastic polymer; and

(b) a plurality of fasteners to fasten the siding units to a building substrate.

33. The siding assembly of claim 32, further including a building interface trim unit.

34. The siding assembly of claim 33, wherein the building interface trim unit is made of a thermoplastic-biofiber composite material.

35. The siding assembly of claim 34, wherein the building interface trim unit includes:

(a) an inner surface;

(b) an outer surface;

(c) a first side edge; and

(d) a second side edge parallel to the first side edge and having a serrated profile mating with an outer surface of the siding profile.

36. The siding assembly of claim 32, further including means for butt-joining adjacent siding units.

37. The siding assembly of claim 36, wherein the means for joining adjacent siding units includes a spline sized and configured to fit against an inner surface of the siding profile.

38. The siding assembly of claim 37, wherein the spline is made of a thermoplastic polymer.

39. The siding assembly of claim 38, wherein the spline includes at least one ridge extending along at least a portion of a length of the spline.

40. The siding assembly of claim 39, wherein the spline includes a plurality of ridges vertically spaced and extending along at least a portion of a length of the spline.

41. The siding assembly of claim 32, further including a building substrate.

42. A siding unit formed by the process of fastening a thermoplastic-biofiber composite siding profile to a thermoplastic polymeric upper flange.

43. The siding unit formed by the process of claim 42, wherein the siding profile comprises 50 to 90 parts of biofiber and 10 to 50 parts of polymer per 100 parts of thermoplastic-biofiber composite material.

44. The siding unit formed by the process of claim 42, wherein the upper flange comprises polyvinyl chloride.

45. The siding unit of claim 42, wherein the siding profile has a coefficient of thermal expansion less than a coefficient of thermal expansion of the upper flange.

46. The siding unit of claim 45, wherein the upper flange coefficient of thermal expansion is at least 1.5 times the siding profile coefficient of thermal expansion.

47. The siding unit of claim 45, wherein the upper flange coefficient of thermal expansion is at least 2 times the siding profile coefficient of thermal expansion.

48. The siding unit formed by the process of claim 45, wherein the siding profile coefficient of thermal expansion is less than 4.5 $x10^{-5}$ m/m/°C (2.5 x 10^{-5} in/in/°F).

49. The siding unit formed by the process of claim 45, wherein the upper flange coefficient of thermal expansion is more than 4.5 $x10^{-5}$ m/m/°C (2.5 x 10^{-5} in/in/°F).

50. The siding unit formed by the process of claim 48, wherein the siding profile coefficient of thermal expansion is 3 $x10^{-5}$ m/m/°C (1 x 10^{-5} in/in/°F).

51. The siding unit formed by the process of claim 49, wherein the upper flange coefficient of thermal expansion is 6 $x10^{-5}$ m/m/°C (3.4 x 10^{-5} in/in/°F).

52. The siding unit formed by the process of claim 42, wherein at least a portion of the upper flange is overlapping the siding profile.

53. The siding unit formed by the process of claim 52, wherein the upper flange is fastened to the siding profile by an ultrasonic or thermal weld.

54. The siding unit formed by the process of claim 42, further including means for supporting the siding profile or a second siding profile substantially parallel to the siding profile and overlapping the upper flange.

55. The siding unit formed by the process of claim 54, wherein the means for supporting the siding profile includes a projection on an inner surface of the siding profile.

56. The siding unit of formed by the process claim 55, wherein the projection is made of a thermoplastic-biofiber composite material, a thermoplastic material or a foam.

57. The siding unit formed by the process of claim 55, wherein the projection is made of a porous thermoplastic-biofiber composite material.

58. The siding unit formed by the process of claim 54, wherein the means for supporting the second siding profile substantially parallel to the siding profile and overlapping the upper flange includes a fin integral with the upper flange and distal to the siding profile.

59. The siding unit formed by the process of claim 54, wherein the means for supporting the second siding profile substantially parallel to the siding profile and overlapping the upper flange includes an arch integral with the upper flange and distal to the siding profile.

60. The siding unit formed by the process of claim 58, wherein the fin is made of a thermoplastic-biofiber composite material, a thermoplastic material or a foam.

61. The siding unit formed by the process of claim 59, wherein the arch is made of a thermoplastic-biofiber composite material, a thermoplastic material or a foam.

62. The siding unit formed by the process of claim 42, wherein the siding profile includes an inner surface and an outer surface defining a cavity.

63. The siding unit formed by the process of claim 62, wherein at least a portion of the cavity comprises a porous thermoplastic-biofiber composite material or a foam.

64. The siding unit formed by the process of claim 42, wherein the siding profile is a solid member.

65. The siding unit formed by the process of claim 64, wherein the siding profile has a thickness of 2.5 mm (0.10 in) to 3.8 mm (0.15 in).

66. The siding unit formed by the process of claim 64, wherein the siding profile has a thickness of 3.2 mm (0.12 in).

67. The siding unit formed by the process of claim 42, wherein the siding profile includes a layer of capstock over at least a portion of the siding profile.

68. The siding unit formed by the process of claim 42, wherein the upper flange includes a plurality of elongated slots in an offset vertical relation.

69. The siding unit formed by the process of claim 42, wherein the siding profile is a single-face profile.

70. The siding unit formed by the process of claim 42, wherein the siding profile is a double-face profile.

71. The siding unit formed by the process of claim 42, wherein an outer surface of the siding profile is convex.

72. The siding unit formed by the process of claim 42, wherein an outer surface of the siding profile is planar.

73. The siding unit formed by the process of claim 42, wherein the thermoplastic-biofiber composite siding profile is formed by extrusion.

74. The siding unit formed by the process of claim 42, wherein the thermoplastic polymeric upper flange is formed by extrusion.

75. A method of manufacturing a siding unit comprising:
(a) forming a siding profile;
(ii) forming an upper flange; and
(iii) fastening the siding profile to the upper flange.

76. The method of manufacturing a siding unit of claim 75, wherein the siding profile is made of a thermoplastic-biofiber composite and the upper flange is made of a thermoplastic polymer.

77. The method of manufacturing a siding unit of claim 75, wherein the siding profile comprises 50 to 90 parts of biofiber and 10 to 50 parts of polymer per 100 parts of thermoplastic-biofiber composite material.

78. The method of manufacturing a siding unit of claim 75, wherein the upper flange comprises polyvinyl chloride.

79. The siding unit of claim 75, wherein the siding profile has a coefficient of thermal expansion less than a coefficient of thermal expansion of the upper flange.

80. The siding unit of claim 79, wherein the upper flange coefficient of thermal expansion is at least 1.5 times the siding profile coefficient of thermal expansion.

81. The siding unit of claim 79, wherein the upper flange coefficient of thermal expansion is at least 2 times the siding profile coefficient of thermal expansion.

82. The method of manufacturing a siding unit of claim 79, wherein the siding profile coefficient of thermal expansion is less than 4.5 $\times 10^{-5}$ m/m/°C (2.5 x 10^{-5} in/in/°F).

83. The method of manufacturing a siding unit of claim 79, wherein the upper flange coefficient of thermal expansion is more than 4.5 $\times 10^{-5}$ m/m/°C (2.5 x 10^{-5} in/in/°F).

84. The method of manufacturing a siding unit of claim 82, wherein the siding profile coefficient of thermal expansion is 3 $\times 10^{-5}$ m/m/°C (1 x 10^{-5} in/in/°F).

85. The method of manufacturing a siding unit of claim 83, wherein the upper flange coefficient of thermal expansion is 6 $\times 10^{-5}$ m/m/°C (3.4 x 10^{-5} in/in/° F).

86. The method of manufacturing a siding unit of claim 75, wherein at least a portion of the upper flange is overlapping the siding profile.

87. The method of manufacturing a siding unit of claim 83, wherein the upper flange is fastened to the siding profile by an ultrasonic or thermal weld.

88. The method of manufacturing a siding unit of claim 75, further including means for supporting the siding profile or a second siding profile substantially parallel to the siding profile and overlapping the upper flange.

89. The method of manufacturing a siding unit of claim 88, wherein the means for supporting the siding profile includes a projection on an inner surface of the siding profile.

90. The method of manufacturing a siding unit of claim 89, wherein the projection is made of a thermoplastic-biofiber composite material, a thermoplastic material or a foam.

91. The method of manufacturing a siding unit of claim 89, wherein the projection is made of a porous thermoplastic-biofiber composite material.

92. The method of manufacturing a siding unit of claim 88, wherein the means for supporting the second siding profile substantially parallel to the siding profile and overlapping the upper flange includes a fin integral with the upper flange and distal to the siding profile.

93. The method of manufacturing a siding unit of claim 88, wherein the means for supporting the second siding profile substantially parallel to the siding profile and overlapping the upper flange includes an arch integral with the upper flange and distal to the siding profile.

94. The method of manufacturing a siding unit of claim 92, wherein the fin is made of a thermoplastic-biofiber composite material, a thermoplastic material or a foam.

95. The method of manufacturing a siding unit of claim 93, wherein the arch is made of a thermoplastic-biofiber composite material, a thermoplastic material or a foam.

96. The method of manufacturing a siding unit of claim 75, wherein the siding profile includes an inner surface and an outer surface defining a cavity.

97. The method of manufacturing a siding unit of claim 96, wherein at least a portion of the cavity comprises a porous thermoplastic-biofiber composite material or a foam.

98. The method of manufacturing a siding unit of claim 75, wherein the siding profile is a solid member.

99. The method of manufacturing a siding unit of claim 98, wherein the siding profile has a thickness of 2.5 mm (0.10 in) to 3.8 mm (0.15 in).

100. The method of manufacturing a siding unit of claim 98, wherein the siding profile has a thickness of 3.2 mm (0.12 in).

101. The method of manufacturing a siding unit of claim 75, wherein the siding profile includes a layer of capstock over at least a portion of the siding profile.

102. The method of manufacturing a siding unit of claim 75, wherein the upper flange includes a plurality of elongated slots in an offset vertical relation.

103. The method of manufacturing a siding unit of claim 75, wherein the siding profile is a single-face profile.

104. The method of manufacturing a siding unit of claim 75, wherein the siding profile is a double-face profile.

105. The method of manufacturing a siding unit of claim 75, wherein an outer surface of the siding profile is convex.

106. The method of manufacturing a siding unit of claim 75, wherein an outer surface of the siding profile is planar.

107. The method of manufacturing a siding unit of claim 75, wherein the thermoplastic-biofiber composite siding profile and thermoplastic polymeric upper flange are formed by extrusion.

108. The method of manufacturing a siding unit of claim 107, wherein the upper flange is fastened to the thermoplastic-biofiber composite siding profile during the extrusion of the thermoplastic-biofiber composite siding profile.

109. The method of manufacturing a siding unit of claim 107, wherein the thermoplastic-biofiber composite siding profile is fastened to the upper flange during the extrusion of the upper flange.

110. The method of manufacturing a siding unit of claim 107, wherein the thermoplastic-biofiber composite siding profile is fastened to the upper flange during the extrusion of the upper flange and thermoplastic-biofiber composite siding profile.

111. The method of manufacturing a siding unit of claim 107, further including aligning the upper flange and siding profile to maintain an overall manufacturing tolerance less than the manufacturing tolerance of the upper flange added to the manufacturing tolerance of the siding profile.

112. The method of manufacturing a siding unit of claim 75, further including cutting the siding unit to a desired length.

113. The method of manufacturing a siding unit of claim 112, wherein the length is 5 meters (16 feet) or greater.

114. A siding unit manufactured by the method of claim 75.

115. A method of installing siding, comprising:

(a) fastening a siding unit to a building substrate, each unit having:

(i) a siding profile made of a thermoplastic-biofiber composite material; and

(ii) an upper flange fastened to the siding profile where the upper flange is made of a thermoplastic polymer.

116. The method of installing siding of claim 115, further including fastening a building interface trim unit to the building substrate at a building interface.

117. The method of installing siding of claim 116, wherein the building interface trim unit is made of a thermoplastic-biofiber composite material.

118. The method of installing siding of claim 117, wherein the building interface trim unit includes:

(a) an inner surface;

(b) an outer surface;

(c) a first side edge; and

(d) a second side edge parallel to the first side edge and having a serrated profile mating with an outer surface of the siding profile.

119. The method of installing siding of claim 115, further including butt-joining adjacent siding units with means for butt-joining adjacent siding units.

120. The method of installing siding of claim 119, wherein the butt joining adjacent siding units with means for joining adjacent siding units includes fastening a spline sized and configured to fit against an inner surface of the siding profile to an inner surface of a first siding profile and an inner surface of a second adjacent siding profile.

121. The method of installing siding of claim 120, wherein the spline is made of a thermoplastic polymer.

122. The method of installing siding of claim 121, wherein the spline includes at least one ridge extending along at least a portion of a length of the spline.

123. The method of installing siding of claim 122, wherein the spline includes a plurality of ridges vertically spaced and extending along at least a portion of a length of the spline.

124. The method of installing siding of claim 115, further including engaging a second siding unit siding profile with the upper flange of the fastened siding unit.

125. The method of installing siding of claim 124, further including aligning the second siding unit siding profile with the fastened siding unit siding profile.

126. The method of installing siding of claim 125, further including fastening the aligned second siding unit to the building substrate.

127. The method of installing siding of claim 115, wherein the fastening includes hard nailing the siding unit to the building substrate.

128. The method of installing siding of claim 115, wherein the fastening includes loose nailing the siding unit to the building substrate.

129. A building interface trim unit, comprising:
   (a) a elongated body having:
      (i) an inner face;
      (ii) an outer face;
      (iii) a first side edge and;
      (iv) a second side edge parallel to the first side edge and having a serrated profile.

130. The building interface trim unit of claim 129, wherein the building interface trim unit is made of a thermoplastic-biofiber composite material.

131. The building interface trim unit of claim 129, wherein the building interface trim unit comprises 50 to 90 parts of biofiber and 10 to 50 parts of polymer per 100 parts of thermoplastic-biofiber composite material.

FIG. 1A

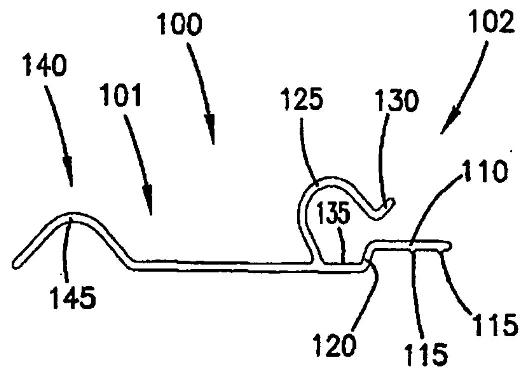
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FIG. 1B

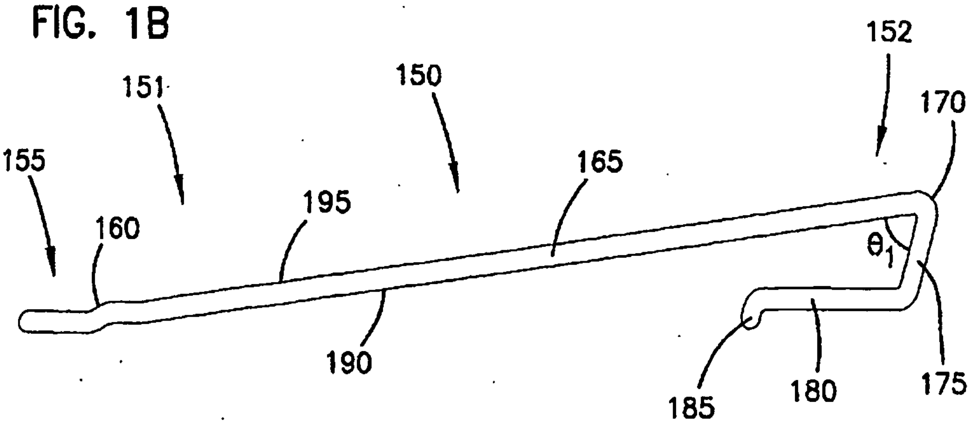
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FIG. 1C

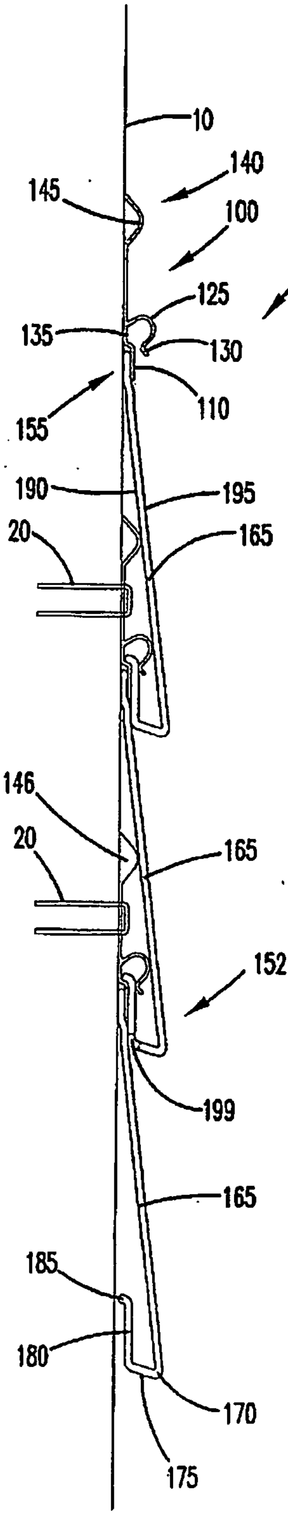
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FIG. 1D

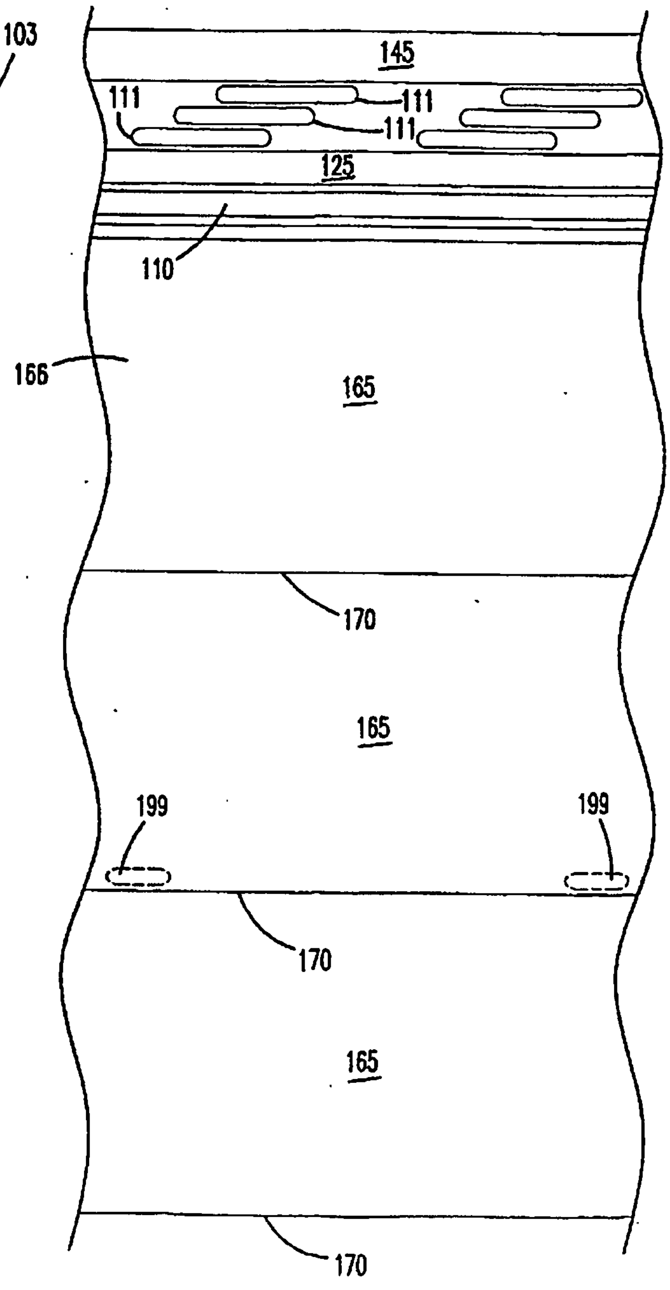
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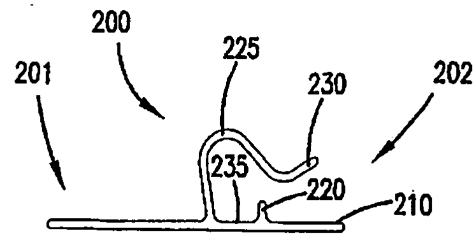
FIG. 2A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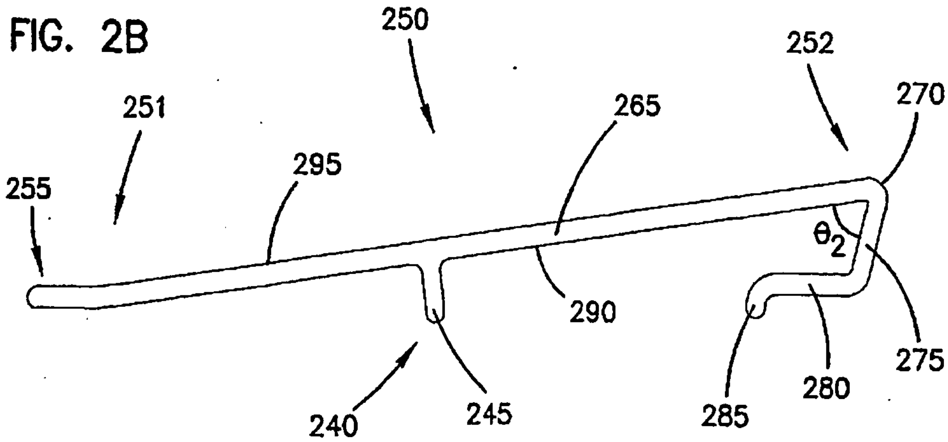
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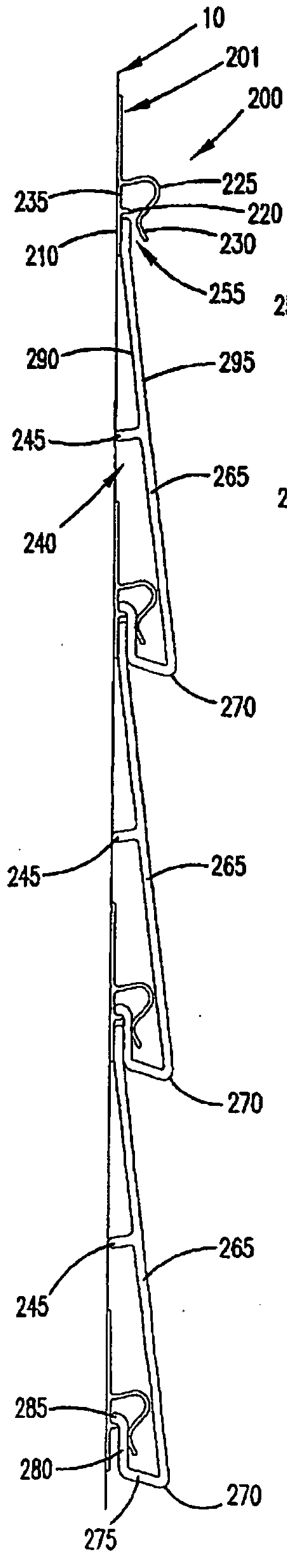
FIG. 2C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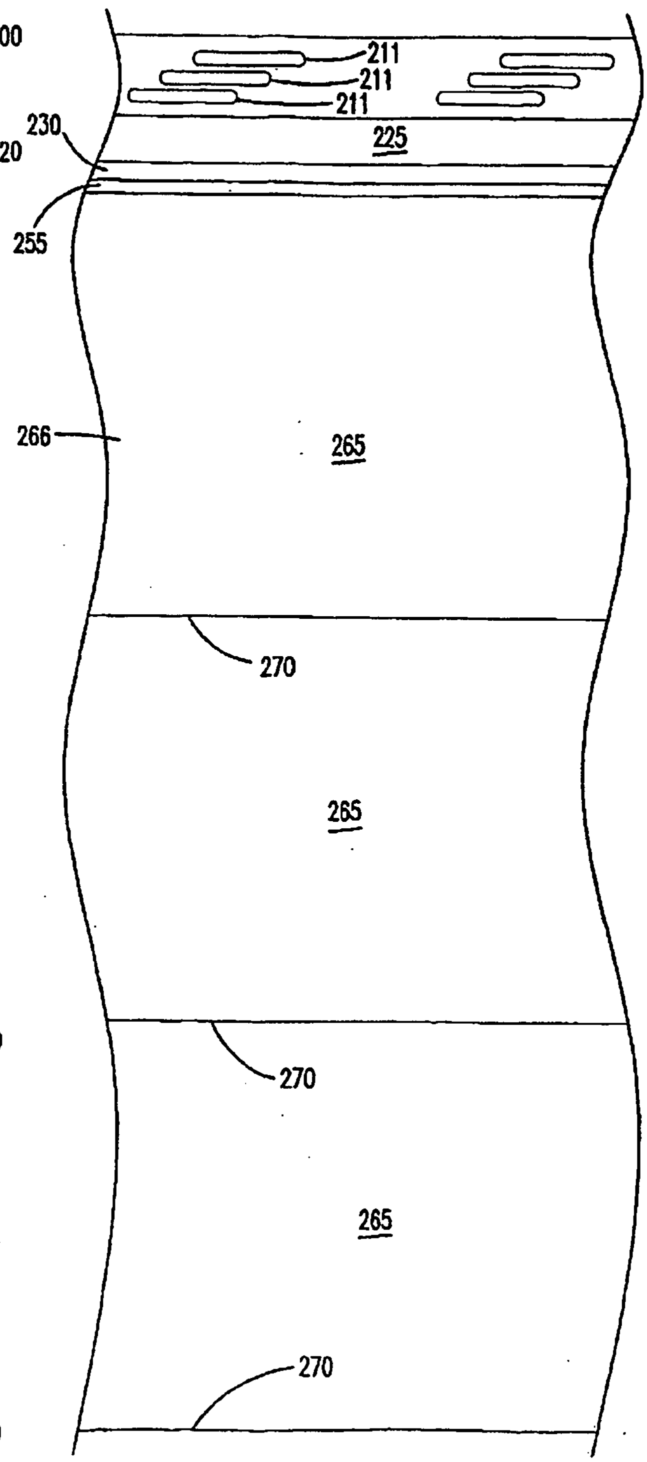
280
270
275

FIG. 2D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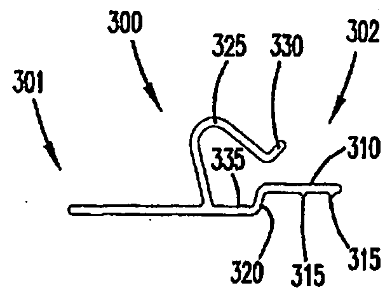
270

FIG. 3A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301
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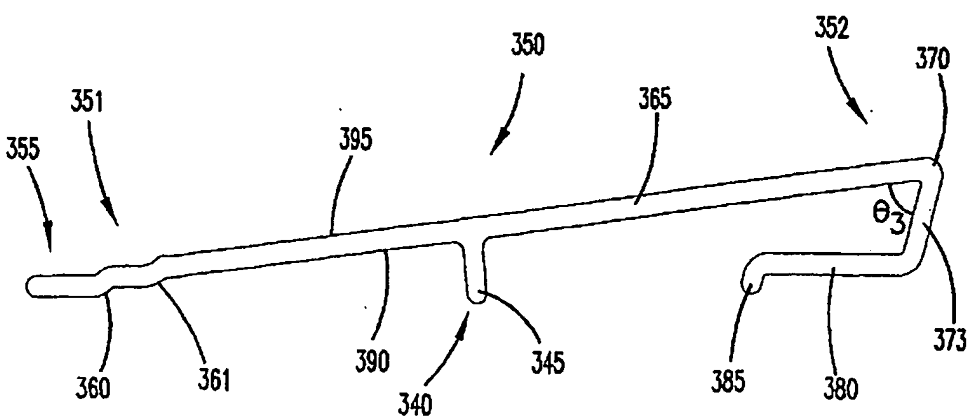
FIG. 3B


350
351
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395
365
370
θ_3
360
361
390
340
345
385
380
373

FIG. 3C

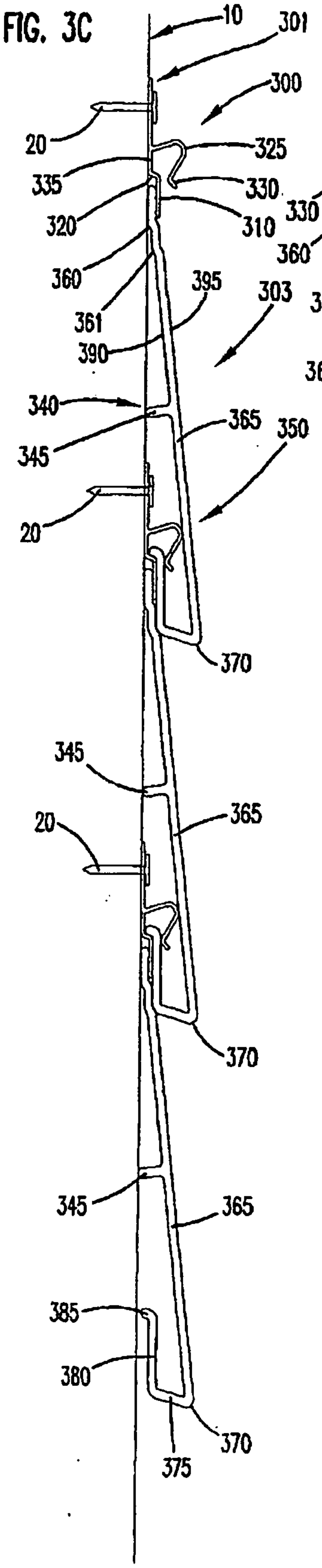
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FIG. 3D

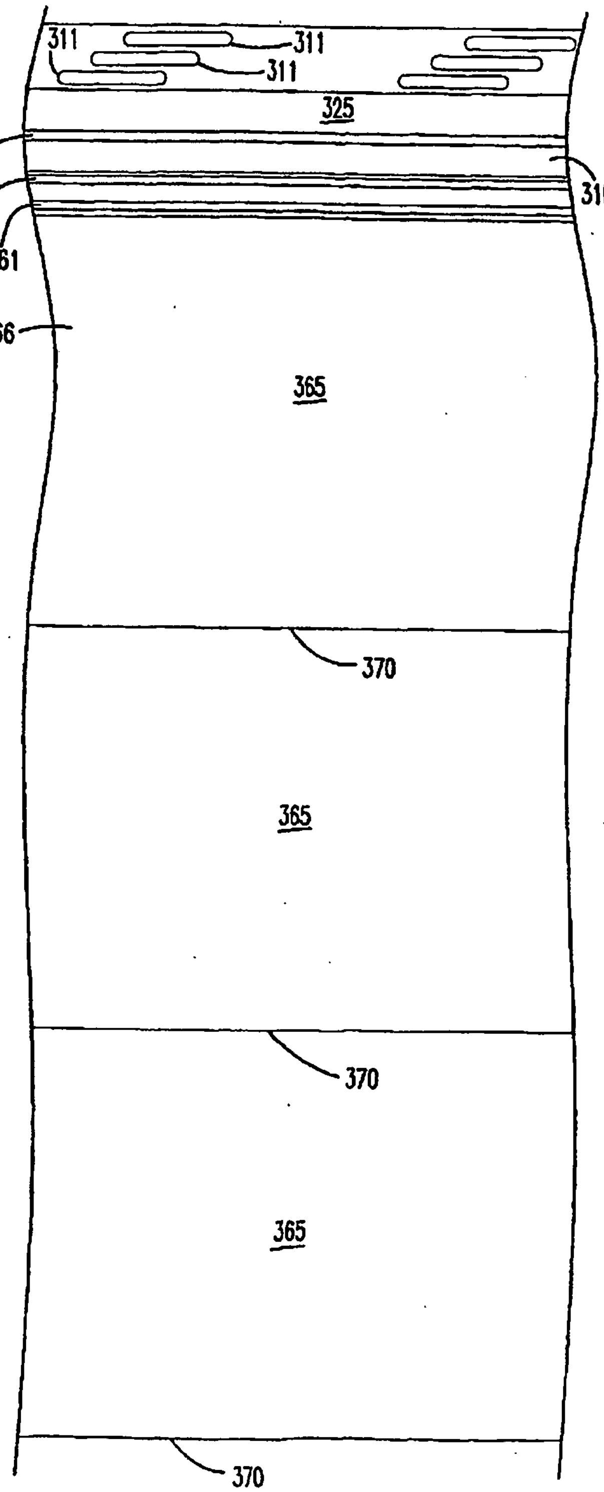
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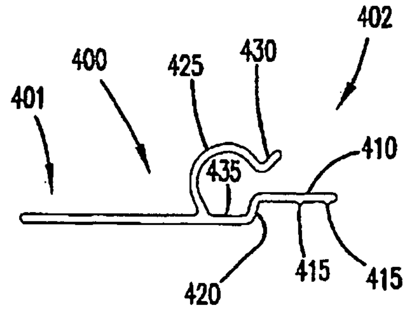
FIG. 4A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435
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415
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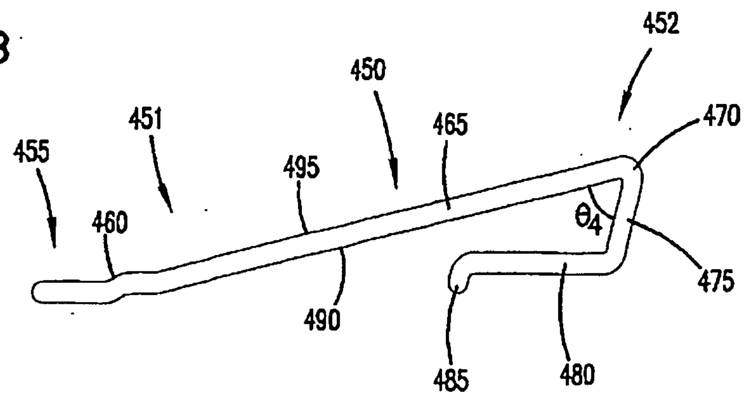
FIG. 4B


452
450
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465
455
495
460
θ_4
475
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485
480

FIG. 4C

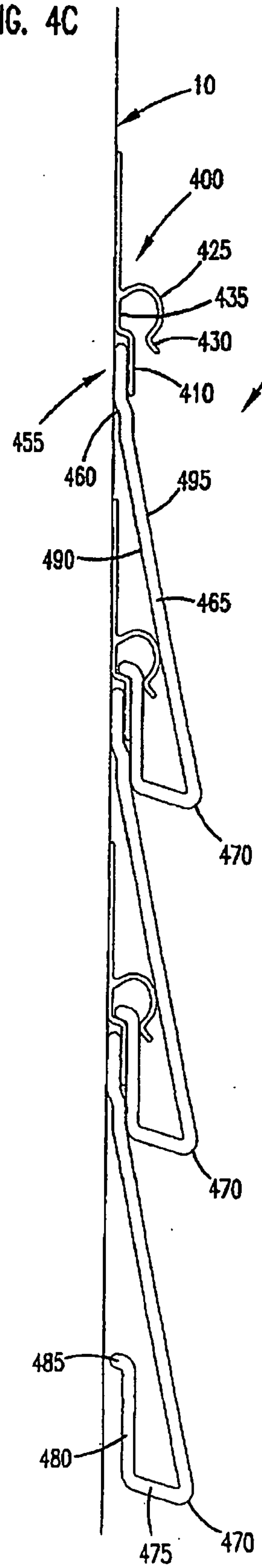
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FIG. 4D

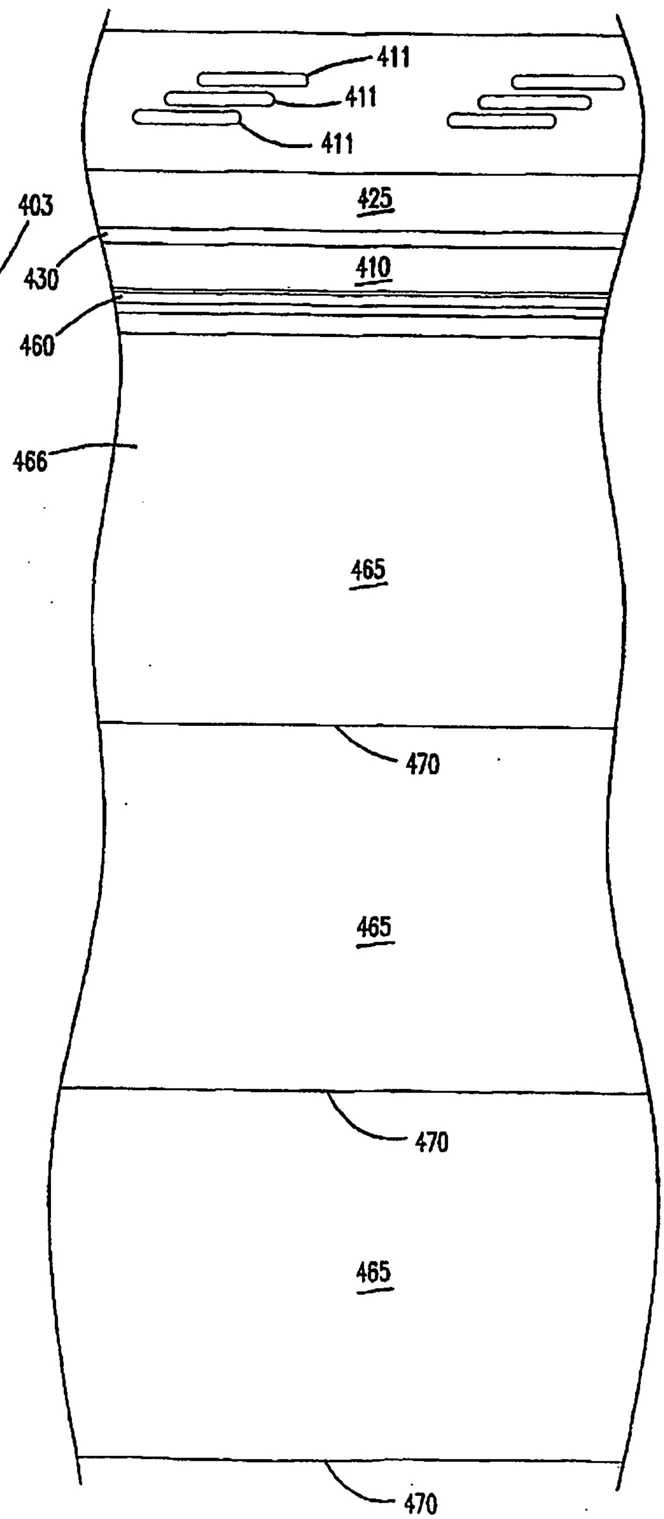
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FIG. 5A

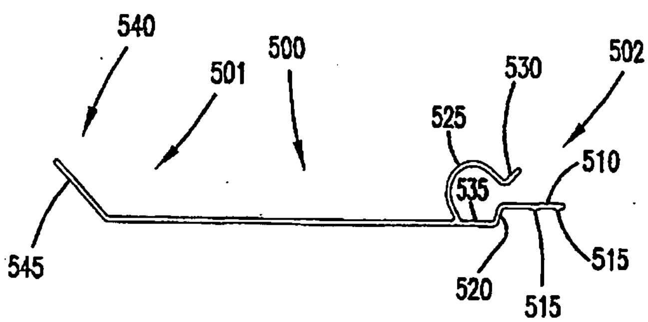

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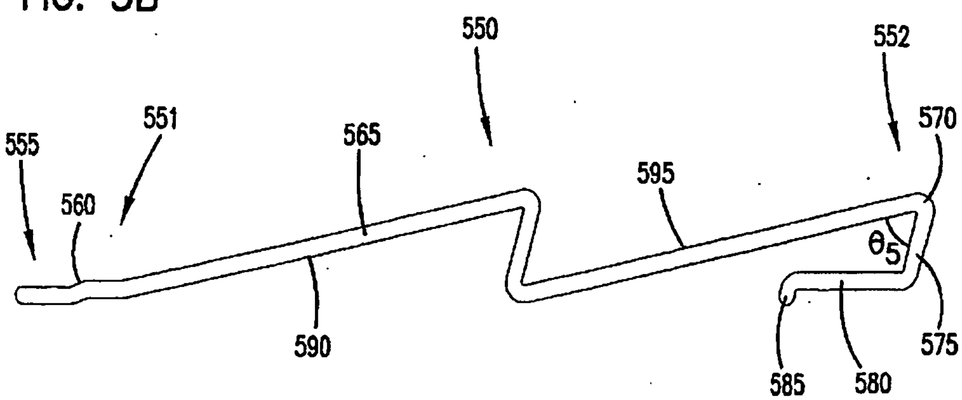
FIG. 5B



550
552
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565
570
595
560
θ_5
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575
585
580

FIG. 5C

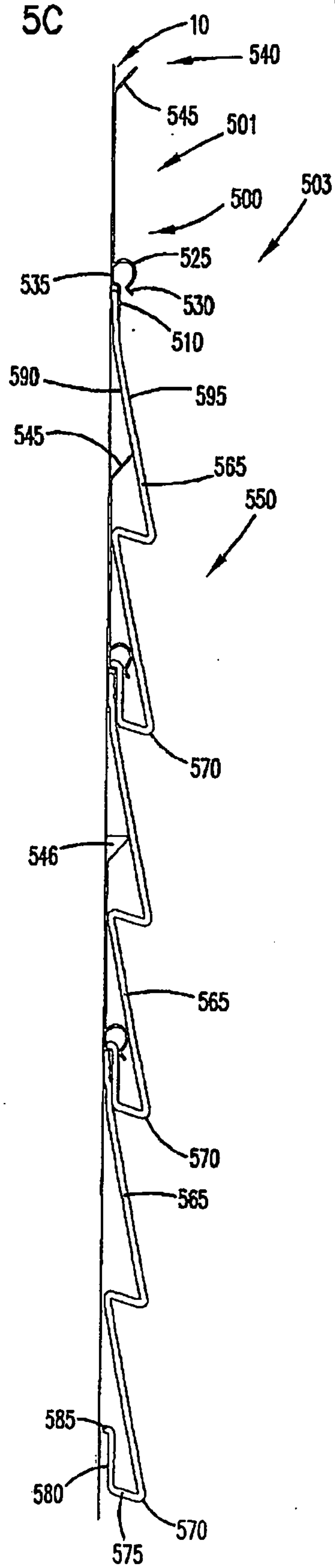
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FIG. 5D

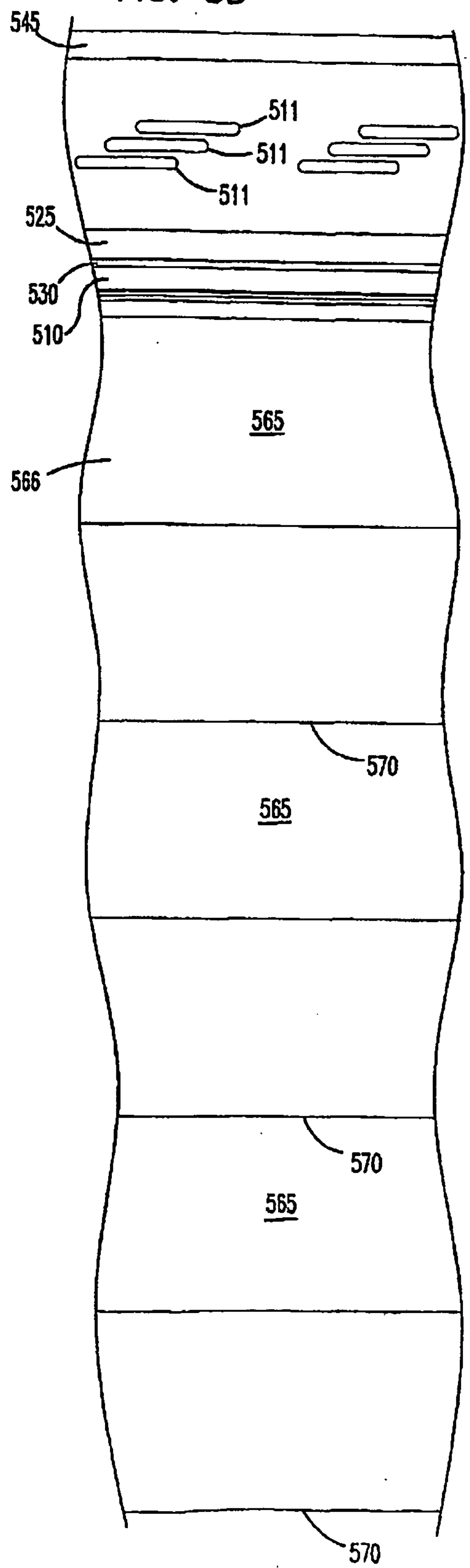
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FIG. 6A

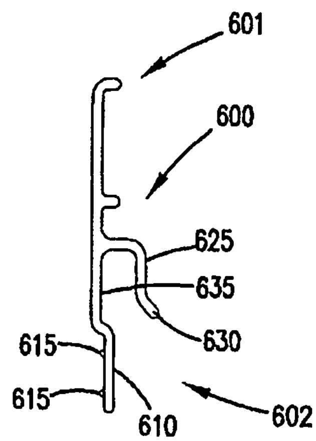
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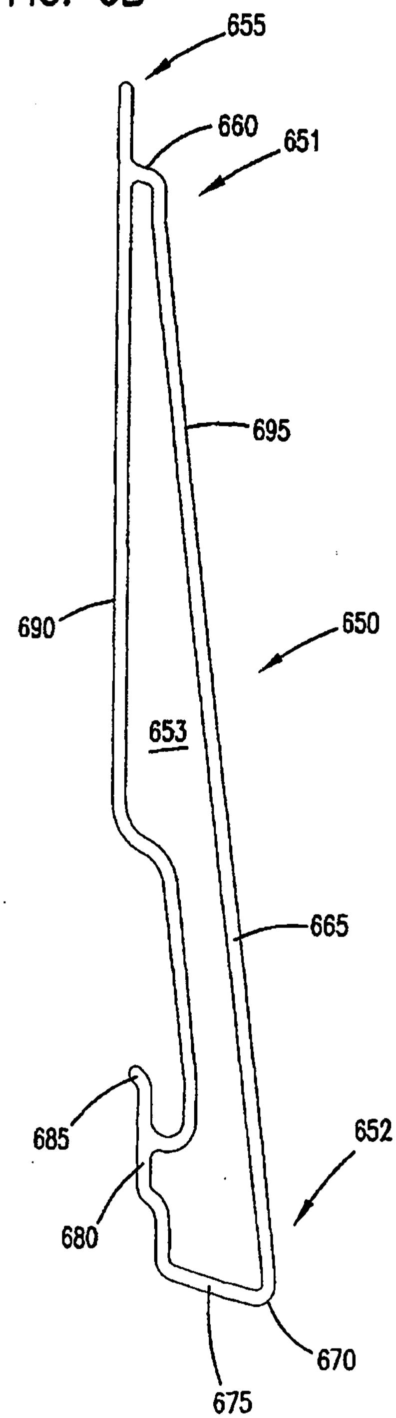
FIG. 6B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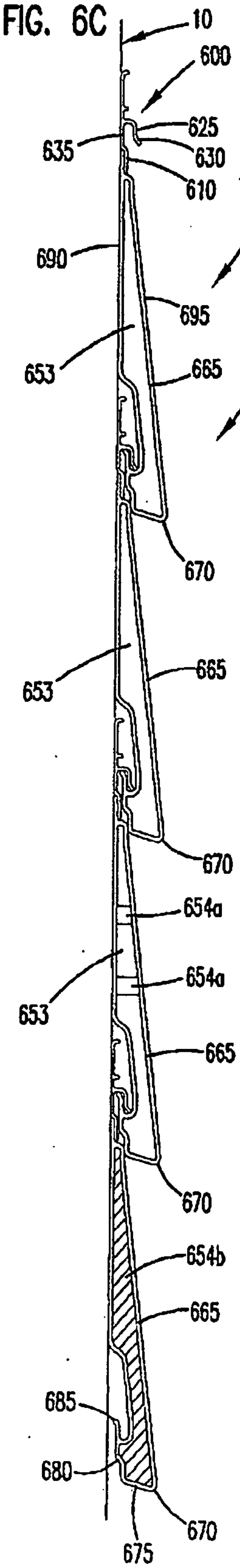
670
675

FIG. 6C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654b
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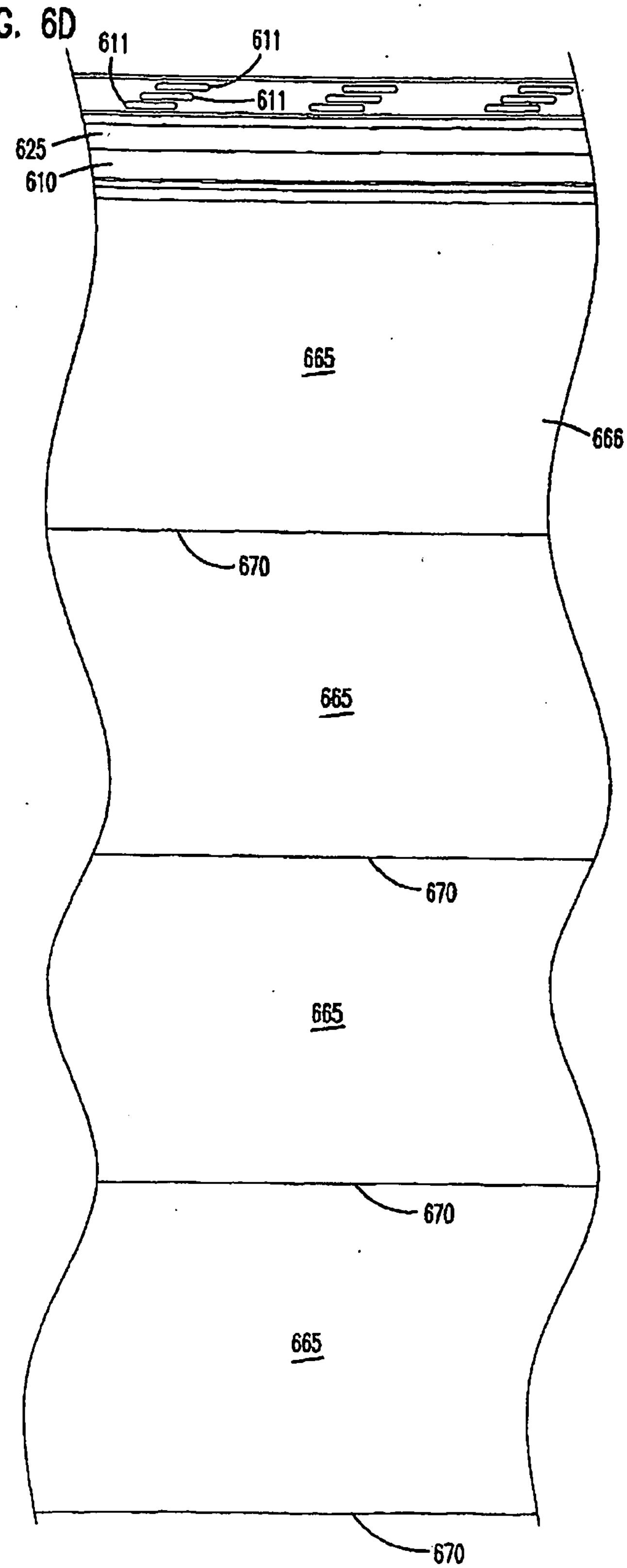
FIG. 6D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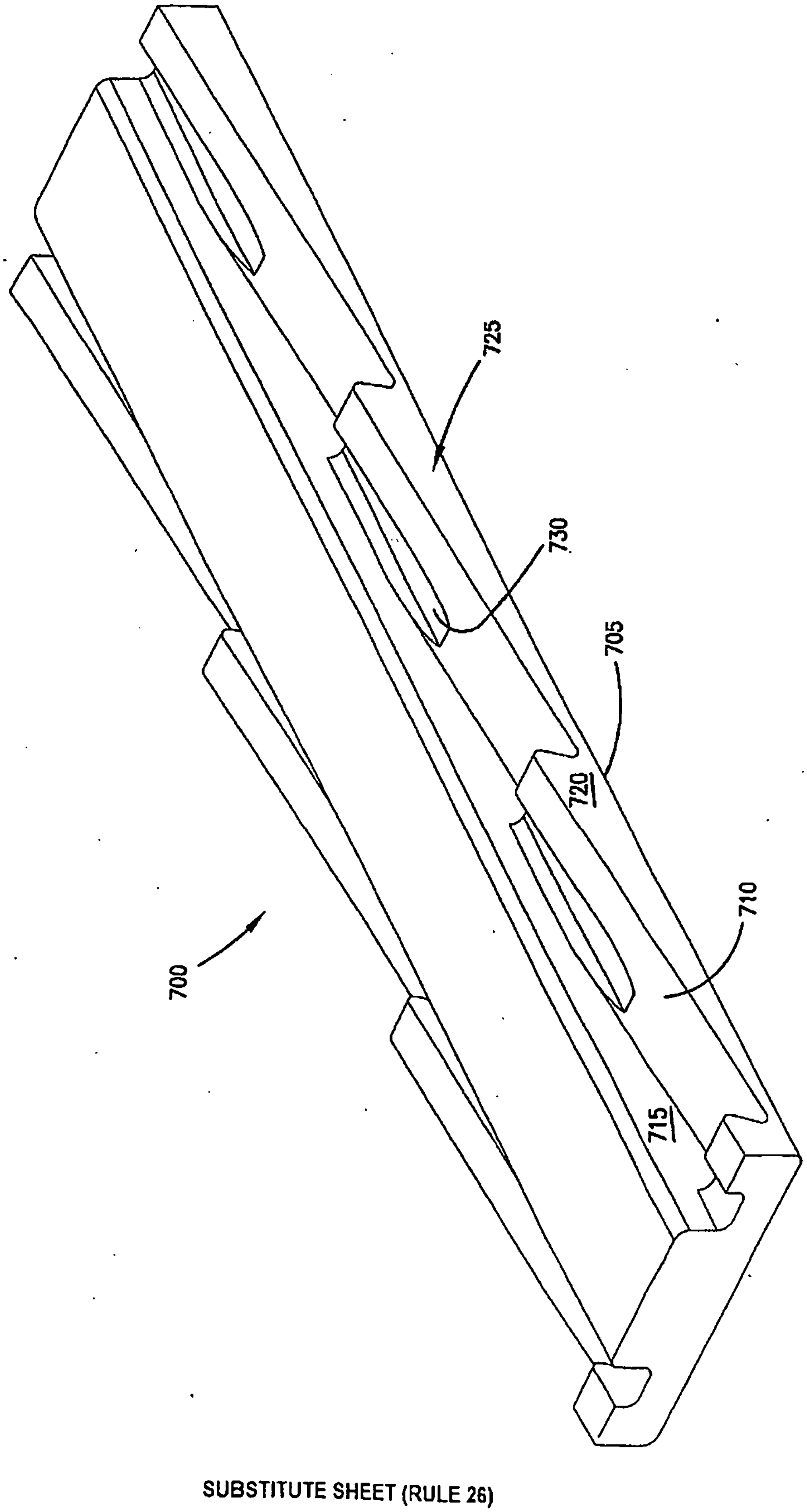


FIG. 7A

FIG. 7B

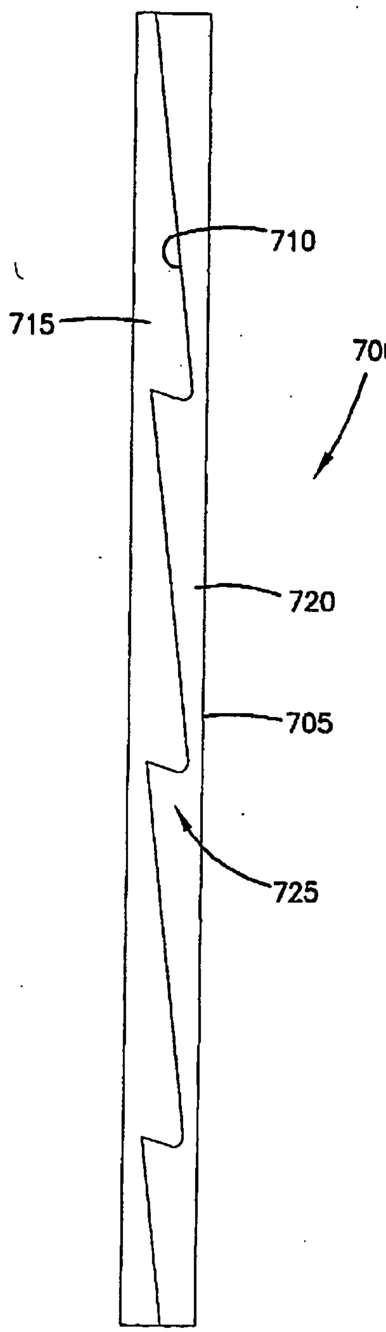


FIG. 7C

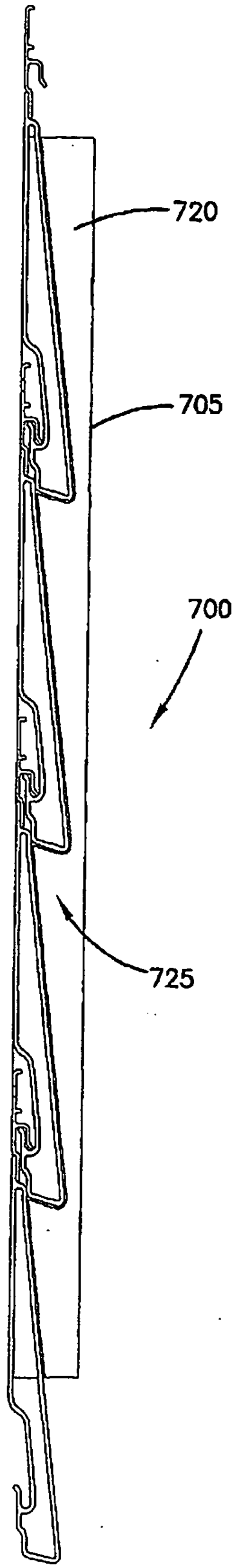


FIG. 7D

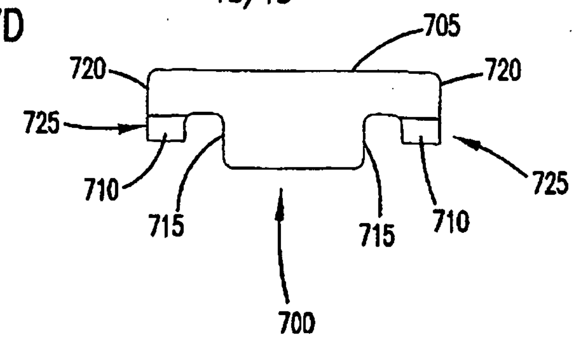


FIG. 7E

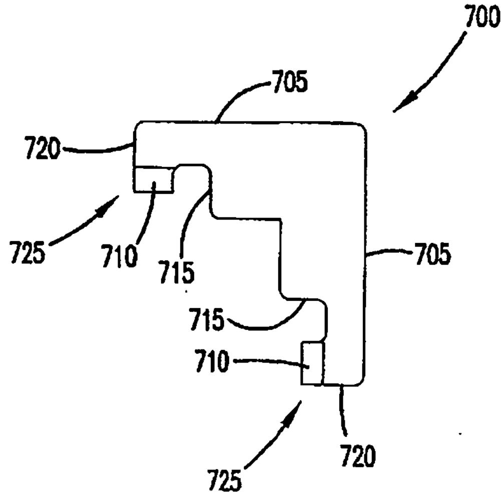


FIG. 7F

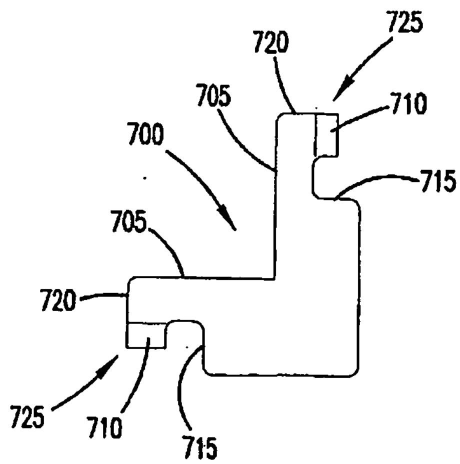


FIG. 7G

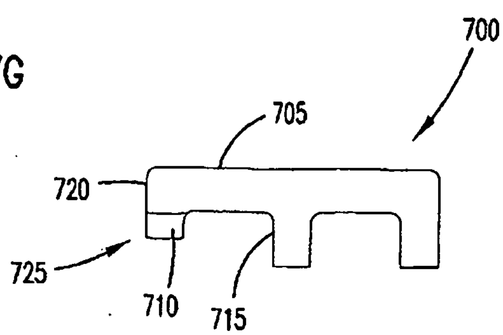


FIG. 8A

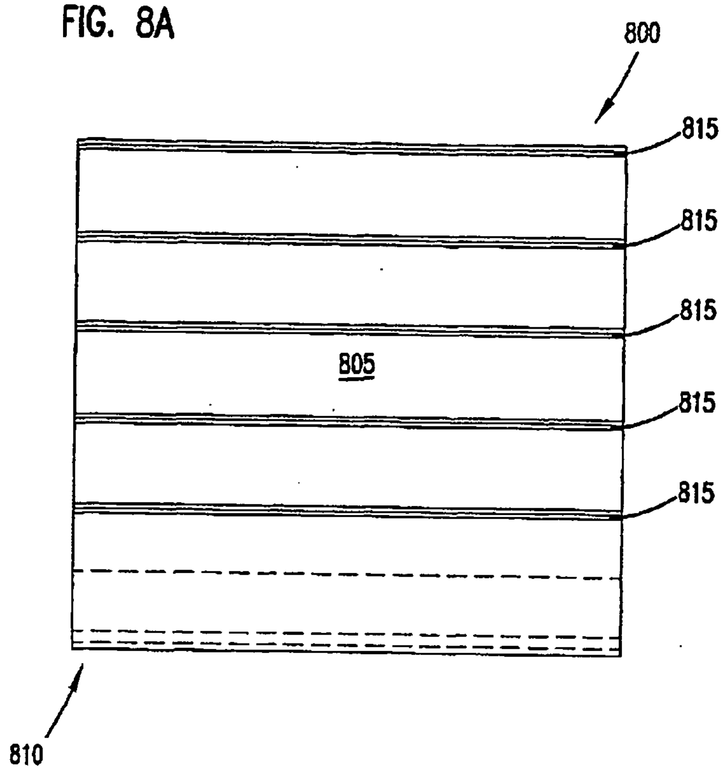


FIG. 8B

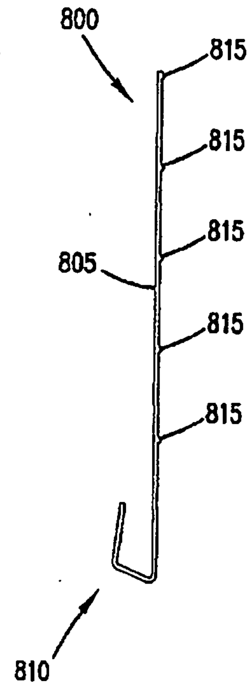


FIG. 9A

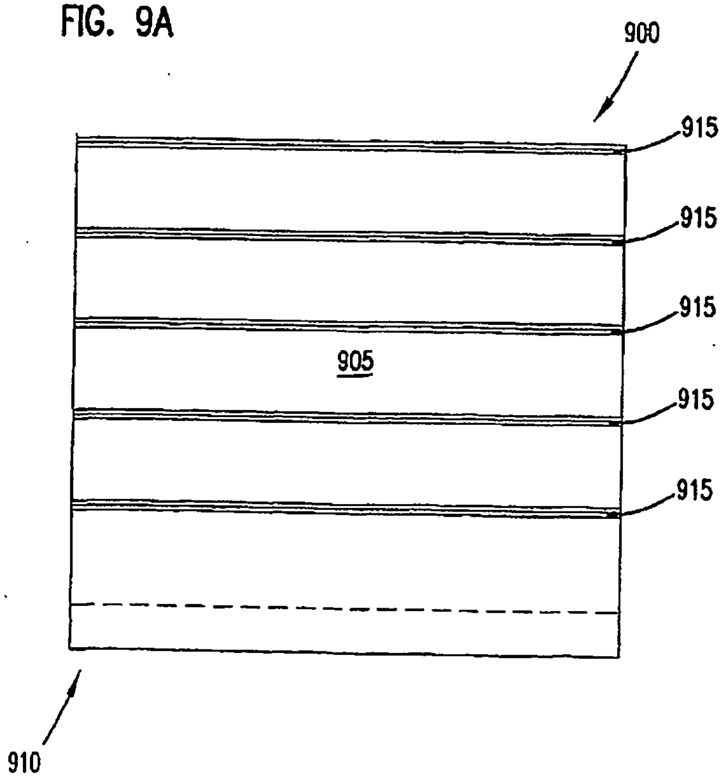
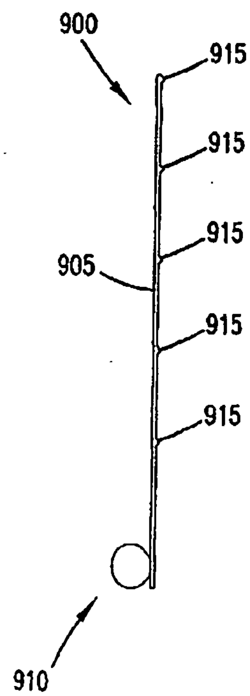


FIG. 9B



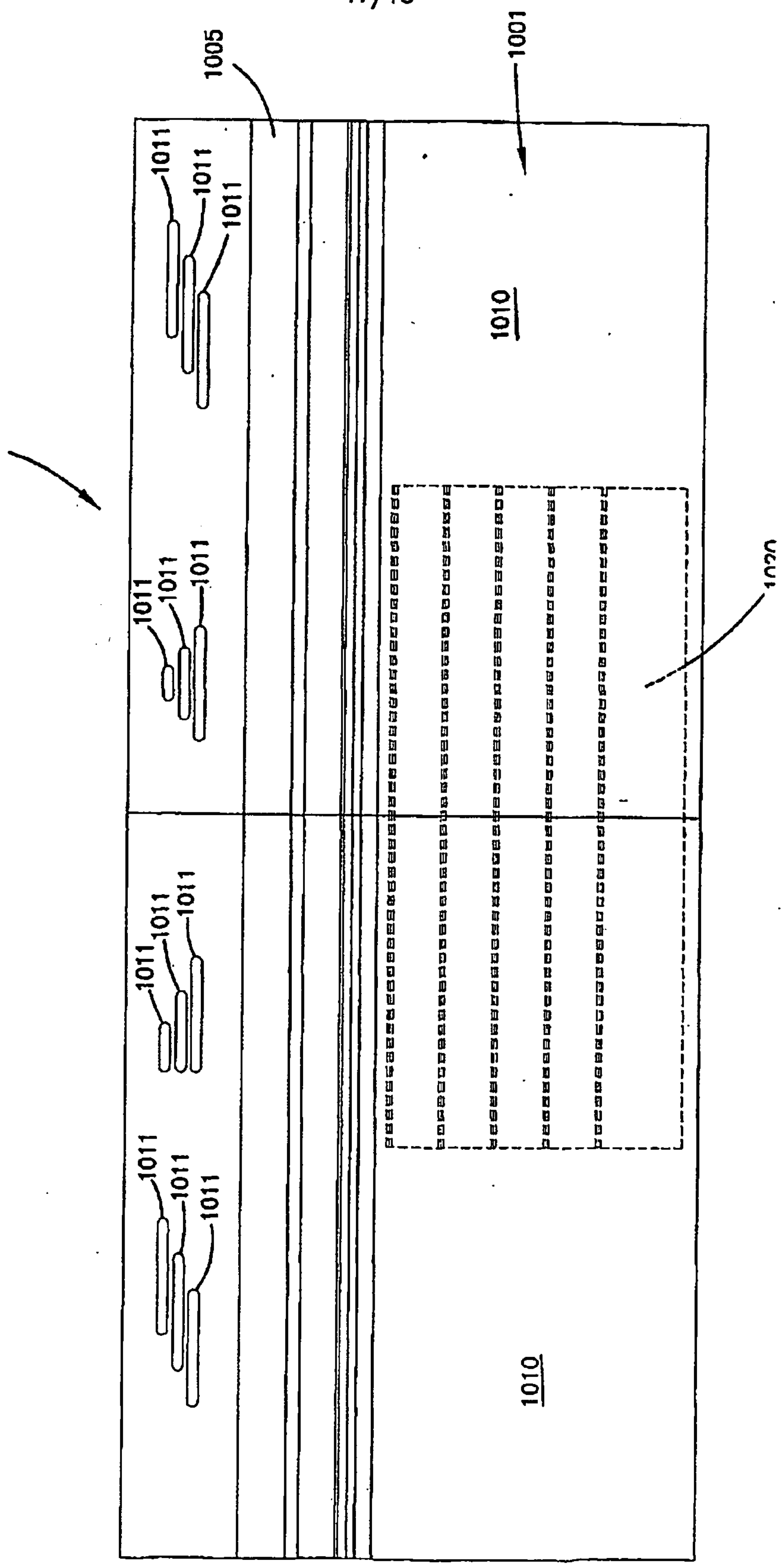


FIG. 10

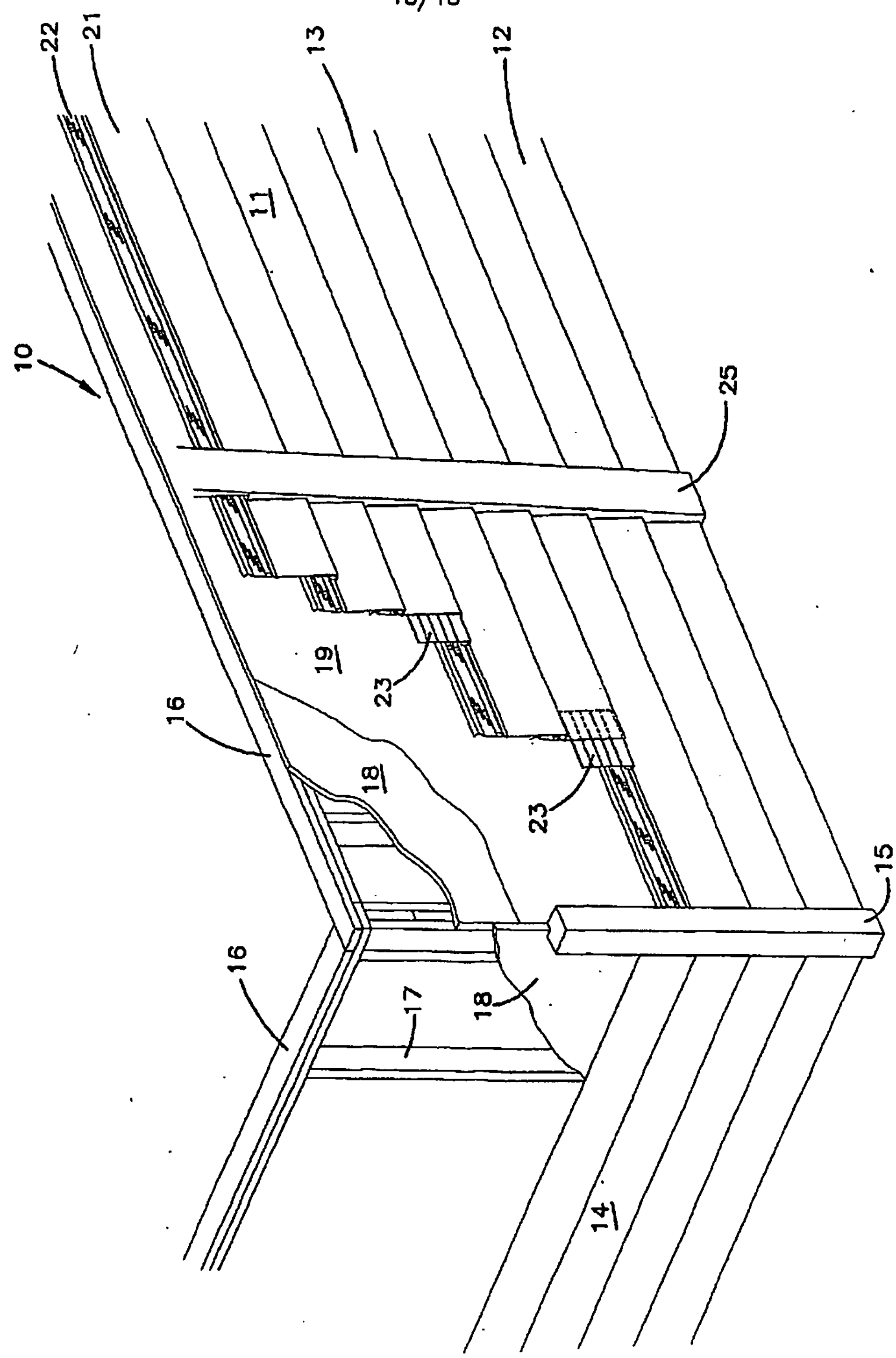


FIG. 11

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 01/00936

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 E04F13/08 E04F13/16

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 E04F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 6 122 877 A (HEIKKILA KURT E ET AL) 26 September 2000 (2000-09-26) the whole document	1-74, 115-128
Y	US 6 134 855 A (BECK DAVID H) 24 October 2000 (2000-10-24) column 2 -column 7; figures 2-25	1-74, 115-128
A	US 3 417 531 A (JONES ROBERT B) 24 December 1968 (1968-12-24) column 1; figures 1,2	1
A	US 4 096 679 A (NAZ PAUL) 27 June 1978 (1978-06-27) column 3, line 29 -column 4, line 32; figures 1,2	1

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
22 June 2001	10. 10. 01

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Bouyssy, V

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 01/00936

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

1-74, 115-128

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest.

☐ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. Claims: 1-74 and 115-128

   A siding unit comprising a siding profile made of thermoplastic-biofiber composite material and an upper flange made of thermoplastic polyester, which upper flange being fastened to the siding profile.

2. Claims: 75-114

   A siding unit comprising a siding profile and an upper flange, wherein the upper flange has been fastened to the siding profile.

3. Claims: 129-131

   A building interface trim unit with a serrated edge.

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 01/00936

Patent document cited in search report		Publication date	Patent family member(s)		Publication date
US 6122877	A	26-09-2000	CA	2238887 A1	30-11-1998
US 6134855	A	24-10-2000	US	5887403 A	30-03-1999
			US	5729946 A	24-03-1998
			US	5857303 A	12-01-1999
			US	6000185 A	14-12-1999
			BR	9705300 A	25-05-1999
			CA	2217914 A1	08-04-1999
			JP	11124949 A	11-05-1999
US 3417531	A	24-12-1968	NONE		
US 4096679	A	27-06-1978	NONE		